Ext. 2814

INSTRUCTION MANUAL

SD-101 DYNAMIC ANALYZER

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CALIBRATION & STANDARDS
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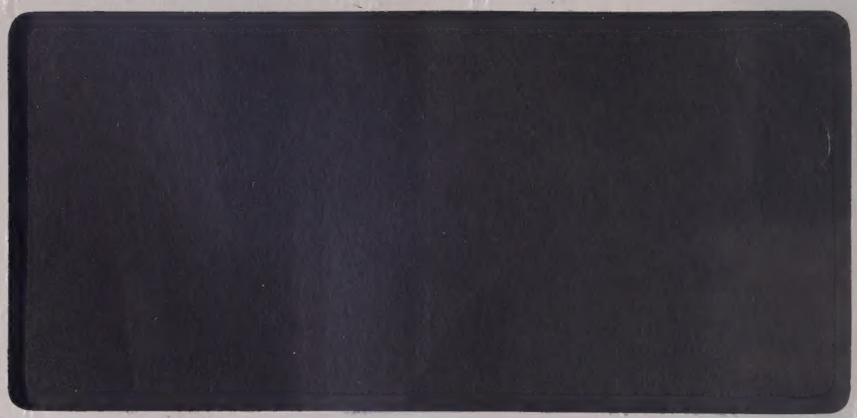
SPECTRAL DYNAMICS CORPORATION OF SAN DIEGO



SERIAL NO. _____

Ext. 2814

INSTRUCTION MANUAL

SD-101 DYNAMIC ANALYZER

PROPERTY OF DEPT. C-260
CALIBRATION & STANDARDS
DO NOT
REMOVE FROM AREA

SPECTRAL DYNAMICS CORPORATION OF SAN DIEGO

1162 Morena Boulevard
San Diego 10, California
Telephone: 714 - 276-2331

January 15, 1963

Model SD-101 Dynamic Analyzer

UNPACKING

The Model SD-101 Dynamic Analyzer is shipped fully assembled in a polystyrene carton which protects the instrument against all normal shipping hazards. To determine possible damage during shipment of the instrument, the procedures given below should be followed:

1. Place the carton upright on the floor and inspect the exterior, making note of any visible damage.

2. Remove and retain all forms and invoices attached to the carton by the carrier.

3. Unseal the top portion of the carton and remove.

4. Lift the instrument out of the carton and place it on a work bench or other flat surface.

5. Inspect the exterior of the Dynamic Analyzer carefully, noting all visible damage.

6. The Dynamic Analyzer may now be checked for functional operation by following the procedure outlined in Section II.

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report forwarded to Spectral Dynamics Corporation of San Diego. The buyer will be advised of the disposition to be made of the equipment and arrangements shall be made for repair or replacement. Include Name, Model Number and Serial Number when referring to this instrument for any reason.

WARRANTY

Spectral Dynamics Corporation of San Diego warrants each instrument manufactured by them to be free from defects in material and workmanship for one year after delivery to the original purchaser. Our liability under this warranty is limited to servicing and adjusting the instrument returned to the factory with transportation charges prepaid by the purchaser. This warranty specifically excludes any liability in regard to electron tubes, batteries, fuses and lamps. If the fault or a portion thereof is determined by us to have been caused by misuse or abnormal conditions of operation, an estimate will be submitted to the purchaser prior to starting the work on the repairs.

If any fault develops, the following steps should be taken:

1. Notify us or our representative in your area, giving full details of the problem, including name, model and serial number of the equipment. Upon receipt of this information, we will submit service data or shipping instructions.

2. On receipt of shipping instructions, forward the instrument prepaid, to the factory or authorized repair station indicated on the instructions.

IPPING

l shipments to the factory should be made via Air Freight. The instrument should be re-
ced in its original shipping carton or in a strong exterior container surrounded by two or
ee inches of excelsior or similar shock-absorbing material.

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Drawing No. 10009 - Block Diagram

Drawing No. 10007 - Schematic

SECTION I

GENERAL INFORMATION

1-1. INTRODUCTION.

The Dynamic Analyzer is a newly developed multipurpose instrument offering exceptional application versatility in the fields of vibration, acoustical and electrical analysis and measurement. Essentially, the analyzer is a frequency-tuned bandpass filter which is frequency-tuned inherently, without depending upon an internal servo, frequency to DC conversion, or phase lock principles for its unique operation. The center frequency of a selected passband is continuously and precisely tuned to track a frequency from an external source. Figure 1 illustrates the concept of operation.

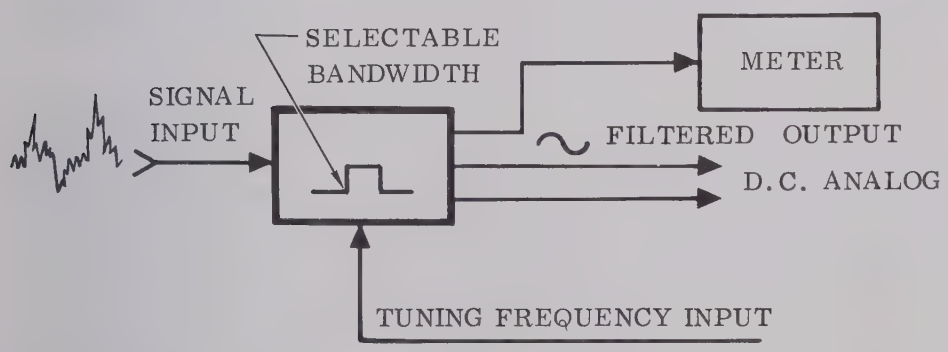


Figure 1. Concept of Operation

The frequency to which the SD-101 is to be tuned is applied to the tuning frequency input. The center frequency of the selected passband is then virtually instantaneously tuned to this external frequency and as the tuning frequency input varies in frequency the center frequency of the passband continuously tracks the tuning signal frequency. The signal to be filtered is applied to the signal input of the analyzer and the SD-101 provides three outputs representing data signals falling within the passband: (1) a meter; (2) a DC analog and (3) a filtered signal output.

2. GENERAL DESCRIPTION.

The instrument is packaged on a 7" x 19" standard panel and a chassis that extends 14" behind the front panel. The chassis has bottom and top dust covers which are perforated for ventilation and are easily removed during maintenance. The top cover should be removed when the equipment is mounted in a closed console. The front panel (figure 2) contains the necessary operating controls, meters, calibration controls and input-output jacks to perform routine calibrating and operating functions. The following is a list of the front panel items and a brief description of their functions.

Power Switch

This selector applies power to the instrument. The STANDBY position applies power to the power supply, the tube filaments and to the ovens for the oscillator crystal and crystal filters. The amber light above the POWER switch denotes the standby position. The ON position of the POWER switch applies B+ to the tubes, and is denoted by a red light.

Signal Input

The signal that is to be analyzed or filtered is applied to these terminals. This input is paralleled to a connector on the rear of the equipment for use when rear wiring is desired.

Tuning Input

The external tuning signal used to tune the analyzer is applied to these terminals. This input is also available on the rear of the chassis. The front panel terminal labeled GND is connected to the chassis and the black terminal is connected to circuit ground. The instrument may be operated in the floating or non-floating mode depending on the connection of the terminal shorting link.

Tuning Amplitude Meter

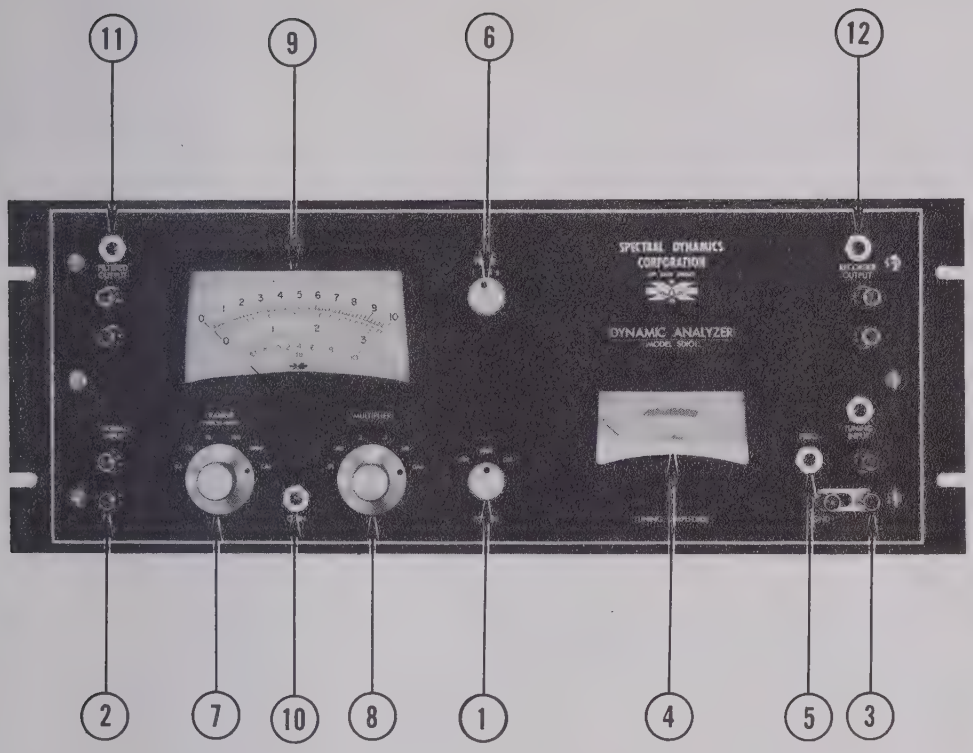
The small meter displays the amplitude of the tuning signal input. A red band on the face of the meter provides a range of the proper operating level. This level can be adjusted by use of the screwdriver adjustment located directly above the tuning input terminals.

Frequency Adjust

This screwdriver adjustment (located between the tuning amplitude meter and the tuning input terminals) is used to adjust the reference oscillator frequency to the center frequency of the crystal filter. It is used during routine calibration procedure.

Filter Selector

The instrument has accommodations for two plug-in crystal filters. This switch is used to



1 POWER SWITCH
2 SIGNAL INPUT
3 TUNING SIGNAL INPUT
4 TUNING AMPLITUDE METER
5 FREQUENCY ADJUST
6 FILTER SELECTOR
7 RANGE SELECTOR
8 MULTIPLIER SELECTOR
9 SIGNAL METER
10 GAIN ADJUST
11 FILTERED SIGNAL OUTPUT
12 RECORDER OUTPUT

Figure 2. Front Panel

elect the desired crystal filter. Two potentiometers are located directly behind the front anel on the filter selector switch and are used to normalize the insertion loss variations etween the various crystal filters.

ange Selector

he RANGE switch is calibrated in volts (RMS) and operates the attenuator on the input of the nstrument. The amplitude of the incoming signal should not exceed the selected range. In ne CAL position, a calibration signal is applied internally to the instrument.

Iultiplier Selector

he MULTIPLIER switch operates an attenuator just preceding the meter amplifier. The ombination of the readings on the switch and the RANGE selector provides the operator with ne selected meter range. When performing the internal CAL procedure the MULTIPLIER hould be placed in the CAL position.

NOTE

CAL and 1.0 on the multiplier are common internally.

ignal Meter

he signal meter contains three scales that are selected by use of the RANGE and MULTI-LIER selectors discussed above. One scale is calibrated in DB while the other two are alibrated in RMS voltage.

ain Adjust

his screwdriver adjustment is used to adjust the gain of the system during routine calibra-ion procedure or when making relative amplitude measurements. When making relative neasurements the gain control provides an 11 DB range of adjustment.

iltered Signal Output

he filtered signal output is the signal amplitudes and frequency or frequencies contained in he passband of the instrument. The output level can be adjusted as desired by the adjacent screwdriver control. This output is also available from a rear connector.

ecorder Output

A DC voltage, proportional to the average amplitude of the signals contained in the passband s available at these terminals. The DC level is adjustable by use of the screwdriver adjust-ment directly above the terminals. The recorder output is available from a rear connector.

ddition to the connectors that are paralleled to the input and output terminals on the front el, the following items are also located on the rear of the chassis: (See figure 3.)

rrier Selector

e toggle switch is used to select the internal carrier signal, produced by the reference illator and tuning signal, or an external source. In the external position, this switch also connects B+ from the carrier converter section.

ernal Carrier Input

is BNC-type connector is provided to facilitate the use of an external carrier signal for ing the SD-101. For example, two SD-101 Analyzers can be tuned by a common source nply by connecting the CARRIER OUTPUT of the first SD-101 to the EXTERNAL CARRIER PUT of the second SD-101 and switching the CARRIER SELECTOR of the second SD-101 to EXT position. Then with a tuning signal applied to the TUNING INPUT of the first SD-101, ch SD-101 Analyzers become tuned by a common carrier signal.

ut/Output Connectors

e four input/output connectors located on the rear are in parallel with the input/output con-tors located on the front panel.

se

e fuse used in the SD-101 is a two-amp, slow-blow type.

wer Input

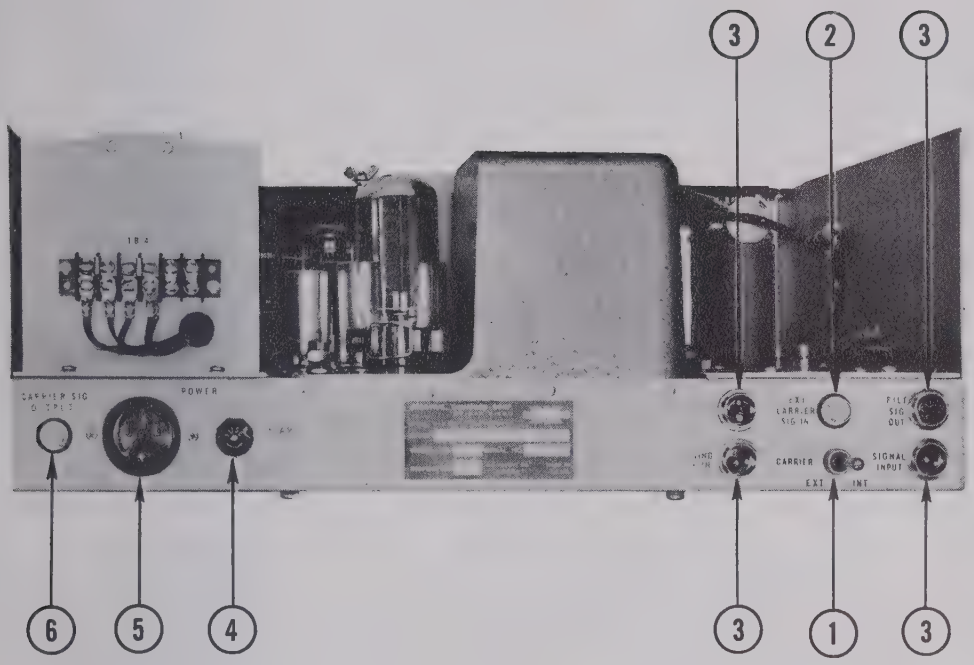
e power input connector accepts a standard three-prong-type power cord.

arrier Output

his BNC-type connector is provided for multichannel systems. An example of its use was plained under the EXTERNAL CARRIER INPUT connector.

-3. SPECIFICATIONS.

Frequency Range:	2 - 25,000 CPS
Useful Frequency Range:	1 - 30,000 CPS
Frequency Response:	Meter and Recorder
	±0.25 DB over operating frequency range



1 CARRIER SELECTOR
2 EXTERNAL CARRIER SIGNAL INPUT
3 INPUT/OUTPUT CONNECTORS
4 FUSE
5 POWER INPUT
6 CARRIER OUTPUT

Figure 3. Rear View

Frequency Response (Con't): Filtered Signal Output

±0.25 DB from 1/2 B.W. to 5 KCPS
Response falls off gradually above 5 KC down approx. 0.5 DB at 10 KC, and approx. 1.25 DB at 25 KC

Note:

1. The operating frequency range is defined as the frequency equal to 1/2 the bandwidth of the filter being used to 25 KCPS.

Example: Using a filter having a bandwidth of 2 CPS, the operating frequency range would be 1/2 B.W. = 1 CPS to 25 KCPS. If the B.W. is 20 CPS, the operating frequency range is 10 CPS to 25 KCPS.

2. The SD-101 can be used below the frequency equal to 1/2 B.W. if some degradation in performance is acceptable. Exceptionally poor response is indicative of excessive unbalance in the signal modulator.

Dynamic Range:

Meter Circuit 60 DB
Filtered Signal Output 50 DB
Linear DC output 30 DB

Linearity:

Meter Circuit ±3% of F.S.
DC Output ±3% of F.S.
Filtered Signal Output ±0.5 DB

Sensitivity:

1 MV - 1000 V Full Scale

Input Impedance:

1 megohm

Tuning Signal:

0.2V (RMS) minimum input required (sinusoidal with less than 5% distortion). SD-101 can be adjusted to be operated with a triangular wave. Allowable amplitude variation is approximately 7 DB.

Selectivity:

Accommodations are provided for two plug-in crystal filters. Standard bandwidths available are 2, 5, 10, 20, 50, and 100 CPS. The shape factor (60 DB/ 3 DB bandwidth) of each filter is nominally 4 to 1. Can be stated as 30 DB per bandwidth octave.

Calibration:	Internal Reference.
Tracking Rate:	The unit tracks at rates in excess of 20,000 CPS/SEC.
Outputs:	1. Recorder 0-1 VDC into 10K. 2. Filtered Signal Adjustable. 10V (RMS) maximum into 100K load.
Power:	105-125 VAC, 50/60/400 CPS. 120 Watts, 230 VAC available by special order.
Input/Output Availability:	All input and output jacks on the front panel are paralleled with connectors on the rear of the unit.
Size:	7 inches high, 19 inches wide and 14 inches deep.
Shipping Weight:	37 LBS.

SECTION II

OPERATING INSTRUCTIONS

.. PRELIMINARY OPERATION CHECKS.

ter Mechanical Zero

eck the meter mechanical zero. If the pointer does not rest directly over the zero with power off, proceed as follows: A stable adjustment can only be made when the direction pointer travel is opposite to the direction of rotation of the adjusting screw. The adjust- screw may be turned in either direction, however, the most effective method is to turn screw clockwise until the pointer swings up-scale and then starts to swing down-scale ward zero. Continue turning the screw clockwise until the pointer (now moving to the left) directly over the zero mark. If the screw is turned too far, continue turning clockwise il the pointer is again traveling down-scale toward zero. Tap the meter lightly to avoid friction in the movement from giving a false indication of zero.

rrier Switch

eck to see that the carrier INT/EXT toggle switch located on the rear of the unit is in INT position.

stallation of Filters

osen the Camloc fasteners, holding the top cover in place by turning the fasteners one-half n counterclockwise. Rotate cover back (cover is rear-hinged), exposing the interior of e equipment. Plug in the crystal filters in the octal sockets marked F1 and F2 located on o of the chassis. F1 and F2 correspond to the front panel filter selector, Positions 1 and respectively. Narrow or broad filters can be installed in any desired order, however the ters are normally installed in the unit and aligned.

sertion Loss Correction Potentiometers

he filter insertion-loss correction potentiometers are multi-turn trimpots located behind e front panel on the filter selector switch. The left-hand potentiometer adjusts the output filter F1 and the right-hand potentiometer adjusts F2. The insertion loss is higher in the rrower bandwidth filters; therefore, the following is the procedure used to normalize the ter insertion loss:

a. Apply power to unit and turn power switch to STANDBY. Allow approximately 15 min- es for warm-up before proceeding.

c. Turn RANGE and MULTIPLIER selectors to CAL position. Turn POWER switch to ON.

. Select FILTER position which selects narrowest filter installed.

. Adjust the FREQUENCY control for a peak indication on the output meter.

. Adjust the front panel GAIN control fully clockwise and then back counterclockwise approximately 1/8 turn.

. Turn the insertion loss potentiometer for a meter reading of 7. If potentiometer fails provide sufficient adjustment to obtain a meter reading of 7, obtain the maximum reading d adjust the GAIN control to obtain the reading of 7.

g. Select the broader filter and turn the corresponding insertion loss potentiometer to btain a meter reading approximately 7 on the meter.

h. Repeat step d and re-adjust insertion loss potentiometer for an exact reading of 7 on the eter.

. Recheck narrow and broad filters being careful to re-peak the frequency control each me a different filter is selected.

NOTE

Before operating the SD-101, study the Block Diagram, Schematic and Application Brochure.

-2. OPERATION.

ilter Center Frequency Alignments and Sensitivity Calibration

n calibrate, the unit's sensitivity is compared against the voltage output of an internal ener diode reference operating at the line frequency. The filter center frequency alignment elative to the tuning frequency, as well as the sensitivity calibration, is performed as llows:

a. Turn on power and allow unit to warm up.

b. Turn RANGE and MULTIPLIER selectors to CAL position. This operation connects the nternal reference to the input of the analyzer, and provides an internal tuning signal to the nit.

c. Select desired filter.

d. Adjust the FREQUENCY control for a peak indication on the output meter.

e. Adjust the GAIN control for an indication of 7 on the output meter.

NOTE

Repeat above procedure when selecting a different filter bandwidth.

f. Apply the tuning frequency and data signal to their proper front or rear connectors. Adjust the tuning signal level control for centerline on the tuning meter.

2-3. SETTING THE RANGE AND MULTIPLIER SWITCHES.

Start measurements with the MULTIPLIER switch in the 1.0 position. Rotate the RANGE switch to obtain an up-scale reading. The purpose of this is to utilize the full dynamic range of the instrument. The filtered signal output is only affected by the RANGE control; therefore, the signal-to-noise ratios are primarily dependent on the RANGE setting.

CAUTION

This input level should not exceed the range control volts RMS. Higher values can overload the input amplifier.

The unit will withstand crest factors (peak/RMS) of approximately 4 to 1 when operating with the maximum RMS input. This ratio goes up proportionally as the input level is less than the range (RMS).

EXAMPLE: RANGE switch set at 1V RMS - input level 0.5V RMS. The input amplifier will now handle crest factors of 8 to 1. This becomes a factor when dealing with random or sine random-type of input signals. However, clipping the large transient peaks of a random signal will not appreciably affect the accuracy of measurement.

2-4. MAKING RELATIVE MEASUREMENTS.

When observing relative levels on the meter, the front panel GAIN control can be used to adjust the reading over an 11 DB range. Adjust for a full-scale reading with the MULTIPLIER on the 1.0 position. Re-establishing the instrument calibration on an absolute basis can be accomplished by repeating the procedure of paragraph 2-2.

2-5. USE OF INTERNAL CAL SIGNAL.

The internal calibration signal applied to the input amplifier of the SD-101 is used to perform filter alignment and sensitivity standardization of the SD-101.

In addition, the calibration signal provides a means for making single-point calibration of auxiliary readout equipment such as X-Y recorders, vibration meters, etc.

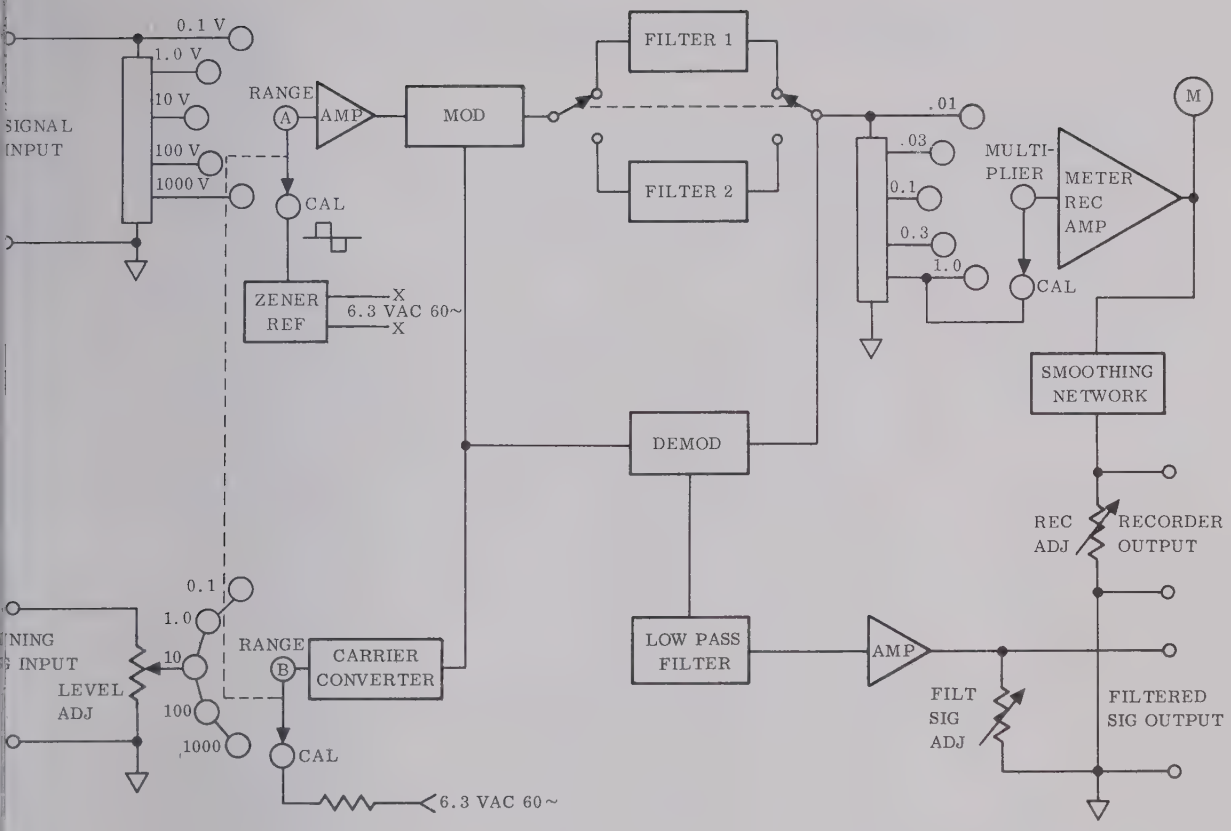


Figure 4. Block Diagram Showing CAL Circuits

With the RANGE and MULTIPLIER in the CAL position a fixed-level 60-cycle tuning signal is applied to the Analyzer Tuning input, disconnecting the external tuning signal. A preset square wave with an equivalent fundamental sinusoidal amplitude of 70 MV RMS is connected to the input amplifier directly, bypassing the input range attenuator.

70 MV into the input amplifier and the SD-101 aligned (Paragraph 2-2) and properly adjusted for a meter reading of 7 on the meter, sets up the proper gain through to the meter circuit so that the amplitude of a selected component of the input signal can be determined from the meter by multiplying the RANGE setting X MULTIPLIER setting = volts full scale.

When the SD-101 is in CAL, output signals are obtained representing the output levels which would be produced by a 70 MV RMS signal applied to the input amplifier. Since an input signal must pass through the input RANGE switch the CAL signal represents a .7X range position during operation.

NOTE

The Range Switch affects all outputs (Meter, Recorder, Filtered Signal). The Multiplier only affects the Meter and Recorder Circuits.

he MULTIPLIER changes the meter and recorder sensitivity 10 DB/step. An equivalent AL output from the Recorder Circuit will increase 10 DB/step on the MULTIPLIER when the operate mode. Therefore, the following formula is used for determining measured tput levels when using the CAL signal before or after a data run to establish a single int calibration.

CAL Output Level (Recorder Output) = .7 X Operating RANGE setting X Operating MULTIPLIER Setting. (RMS Volts)

CAL Output Level (Filtered Signal Output) = .7 X Operating RANGE Setting (RMS Volts)

he RECORDER and FILTERED signal level adjustments can be used to adjust the output vels for scaling purposes.

hese calibration signal outputs can be converted to g levels, velocity levels, etc. by dividg the above equations by the pickup sensitivity in V/g, V/IN./SEC, etc.

-6. TUNING THE SD-101 WITH A TRIANGULAR WAVE.

is often desirable to tune the tracking filter systems with a triangular wave when the tuning ignals are developed by integrating square wave inputs derived from pulse tachometer riggering flip-flop circuits. To adjust the SD-101 for operation with a triangular wave, nject a triangular tuning input and adjust the balance controls as described in paragraph -8. Distortion will be observed in the filtered signal output but this is a constant percenage and is calibrated out through use of the normal calibration procedures.

-7. APPLICATIONS.

efer to Appendix.

SECTION III

THEORY OF OPERATION

-1. INTRODUCTION.

he SD-101 can be considered to be divided into two relatively independent circuit sections:

1. Filtering and measurement section
2. Carrier Converter section

he two operate together to form the frequency-tuned bandpass filter concept. The basic eory of operation can be best explained by referring to the figure below.

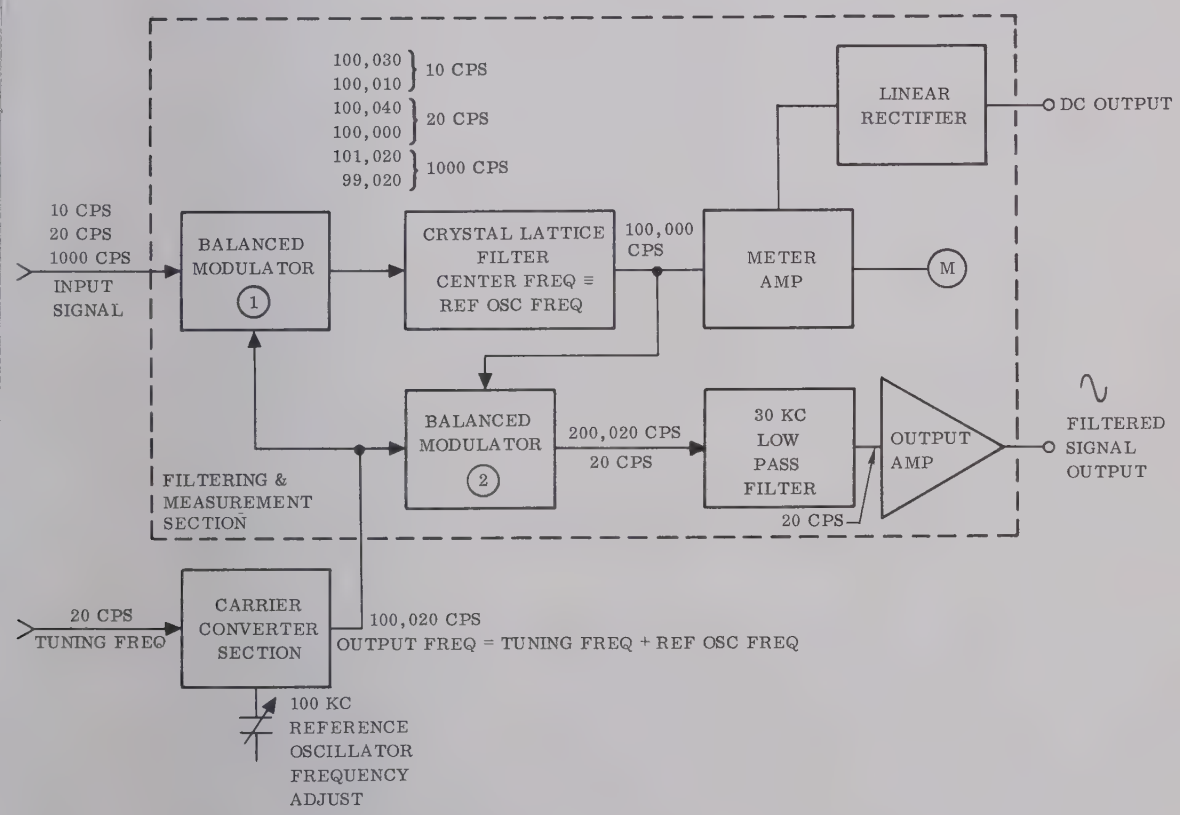


Figure 5. Simplified Block Diagram

Carrier Converter functions to produce an output frequency that is the sum of the tuning quency input and the 100 KC reference oscillator frequency. As an example, with a 20 S tuning signal input the Carrier Converter produces an output of 100,020 CPS. Further, he tuning frequency were to vary from 2 CPS to 25,000 CPS, the output from the Carrier verter would be a frequency varying from 100,002 CPS to 125,000 CPS synchronously h the input tuning signal.

frequency adjustment on the Reference Oscillator varies the reference frequency slightly that the center frequency of the filter and reference oscillator frequency can be adjusted to same frequency. The output of the Carrier Converter is then used to drive two (2) bal-ed modulators in the filtering and measurement section.

show that the SD-101 is adjusted to pass only frequencies lying within the passband of the ler, the following example is used:

sume a complex signal applied to the input of the SD-101, consisting of three frequencies h different amplitudes - 1,000 CPS, 10 CPS, 20 CPS. Assume the Analyzer has a 10 CPS dwidth filter.

xt, assume a tuning frequency of 20 CPS is applied to the tuning input terminals. The put of the Carrier Converter will be 100,020 CPS. The 100,020 CPS signal is applied to balanced modulators 1 and 2. The output of balanced modulator 1 will essentially be the n and difference of the signal frequencies and the Carrier Converter frequency. Since the rrier Converter level is constant for all practical purposes (it can be considered constant ce it is only supplying the switching voltage to the modulator), the amplitudes of the side d frequencies produced will be proportional to the amplitudes of the signal components at Analyzer input. Therefore, at the output of modulator 1, we will have:

(100,020 + 20) = 100,040 CPS; (100,020 - 20) = 100,000 CPS; (100,020 + 10) = 100,030 CPS; (100,020 - 10) = 100,010 CPS; (100,020 + 1000) = 101,020 CPS; (100,020 - 1000) = 99,020 CPS

can be seen from the side band components produced above, only the 20 CPS component plitude will be passed through the crystal band pass filter, with all other components fall-outside the pass band.

e output of the crystal filter is then passed to a meter circuit, indicating the amplitude of signal passed by the filter and also to a rectifier circuit providing a DC output. Addi-nally, the output of the filter is fed to Modulator 2 where it is modulated with the Carrier nverter output. The output of modulator 2 will be the sum and difference frequency of the rrier converter output frequency and the filter output frequency. Carrying the example rough; the output of modulator 2 will be (100,020 + 100,000) = 200,020 and (100,020 CPS 100,000) = 20 CPS. The output of modulator 2 is passed through a 30 KC low pass filter reject the high frequency components, leaving only the 20 CPS component at the low pass ter output.

ext, injecting a tuning frequency of 1000 CPS would provide an output from the Carrier Con-
rter of 101,000 CPS. This applied to modulator 1 results in outputs of:

10 CPS input signal	20 CPS input signal	1000 CPS input signal
(101,010, 100,990);	(101,020, 100,980);	(102,000 and 100,000)

he 100,000 CPS signal will pass through the filter, and (1) its amplitude indicated by the
eter circuit, (2) rectified to provide a DC analog output, and (3) fed to modulator 2 where
is modulated with the 101,000 CPS signal, producing 201,000 CPS and 1000 CPS at modu-
tor 2 output. The 201,000 CPS component is rejected in the low pass filter, leaving only
e 1000 CPS signal at the output.

hus, from the above examples, it can be seen that the center frequency of the unit is tuned
the frequency of an external source.

arrier Converter

he Carrier Converter produces an output frequency that is the sum of the tuning frequency
d the reference oscillator frequency for tuning frequencies ranging from 2 CPS to 25
CPS. The process for accomplishing this is described below:

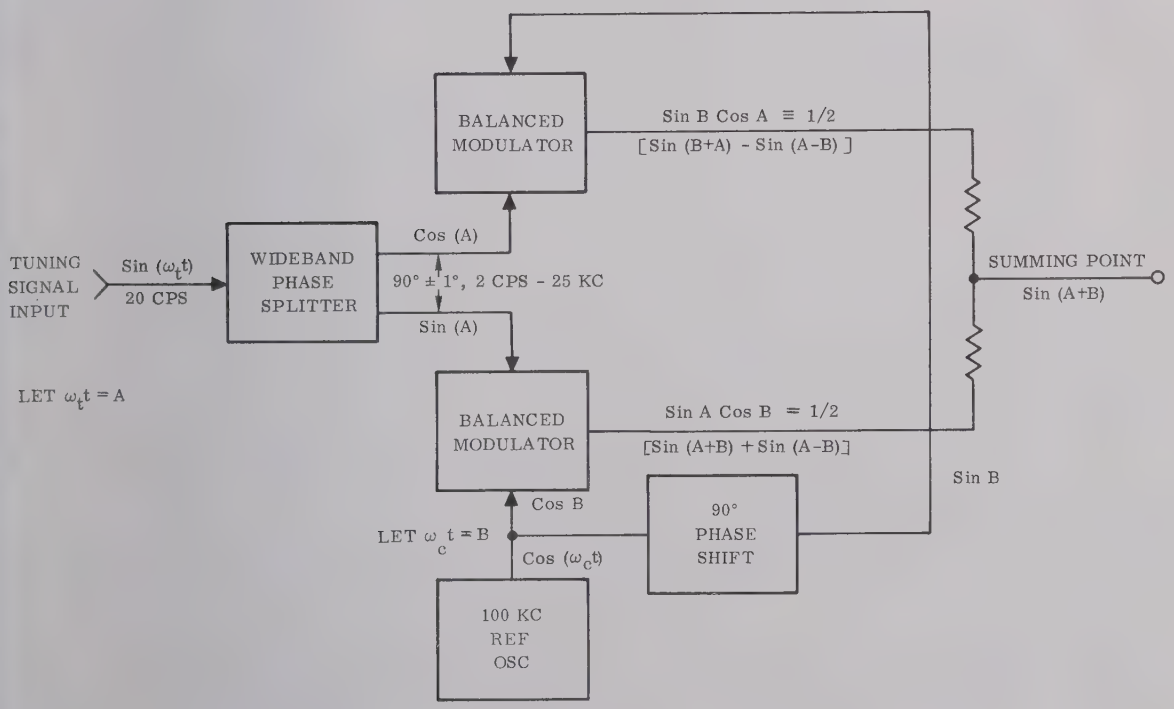


Figure 6. Carrier Converter

he tuning frequency is applied to a wide band phase shift network, producing two output gnals equal in amplitude, but displaced in phase 90° with respect to each other. The outts from the phase shifters are applied to two (2) balanced modulators where they modulate ference oscillator signals. The reference oscillator is also split into two (2) outputs that e 90° apart. The outputs from the balanced modulators are the sum and difference frencies of the reference oscillator and the tuning frequency.

he modulator outputs are then linearily added together and the lower side band frequency is ase and amplitude cancelled, leaving only the sum of the input frequency plus the tuning equency. Reference to figure 6 shows the trigonometric equations indicating how this is complished.

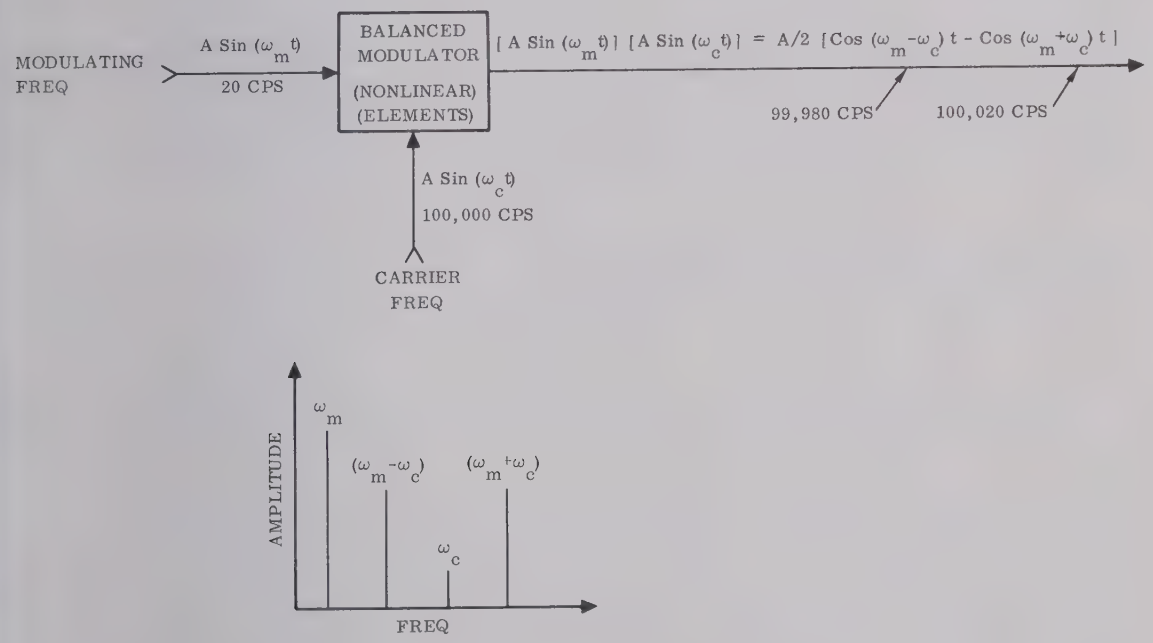


Figure 7. Balanced Modulator

Word About Amplitude Modulation Theory:

Iodulation is basically a process of multiplication.* To accomplish this process with simle analog devices involves the use of some non-linear element, such as diodes, vacuum ubes, varistors, etc.

he SD-101 uses four (4) balanced modulators. The term "balanced" is used to denote a alancing or cancellation of the carrier frequency in the output of the modulator.

* A more thorough treatment of the subject can be found in any standard electronic engineering textbook.

mentioned previously, modulation is basically a process of multiplication. Therefore, illustration purposes, let us examine what occurs when two sine waves are modulated or ltiplied in a balanced modulator:

ferring to the preceding figure, it is seen that two distortionless sine waves ideally mul- lied together have a trigonometric identity as shown, meaning that there are two (2) fre- encies produced at the modulator output; i.e., the lower "sideband" frequency repre- nted by the $(\omega_c - \omega_m)$ term in the trigonometric identity and the upper "sideband" fre- ency represented by the $(\omega_c + \omega_m)$ term.

e carrier frequency used in the SD-101 is 100,000 CPS. The amplitudes of the side band nals on the output of a modulator are identical and proportional to the amplitude of the ut signal amplitude, assuming that the amplitude of the carrier signal applied is constant.

summary, when one signal is modulated by another, output frequencies are produced at e sum and difference of the two frequencies. If the carrier frequency is held constant in plitude, the side band amplitudes are proportional to the input signal amplitude. If a mplex wave is applied to a modulator, side band frequencies due to each of the signal fre- ency components are produced.

gure 7 also shows an example of modulation of 100,000 CPS signal with a 20 CPS signal d the side band frequencies and illustrates graphically the distribution of the two side bands mmetrically about the carrier frequency ω_c.

ernal Calibration Circuit and alignment of Reference Oscillator with filter center equencies:

ncept of the alignment procedure is seen by referring to figure 8a. The purpose of align- ent is to adjust the filter center frequency to be centered at the tuning frequency. In con- pt this could be accomplished by tuning the filter with the same frequency as the data fre- ency. Since the center frequency of the pass band is supposed to be centered at the tuning equency input, we could verify this by simply shifting the center frequency of the filter gher and lower in frequency with respect to the data frequency until the output from the ter reaches a peak. This concept is shown in figure 8a. Figure 8b shows the data fre- ency centered with the filter passband, and figure 8c shows the filter not aligned with e data signal.

ifting the passband relative to the data signal is accomplished by shifting the frequency the reference oscillator with respect to the center of the crystal filter passband. There- re, the front panel adjustment labeled FREQ is in effect shifting the center frequency the passband relative to the tuning signal. Once the filter passband is set relative to the ning frequency it will remain set over the frequency range.

rom the above discussion, it is seen that it is desirable to minimize drift of the 100 KC lter center frequency relative to the reference oscillator frequency. To accomplish

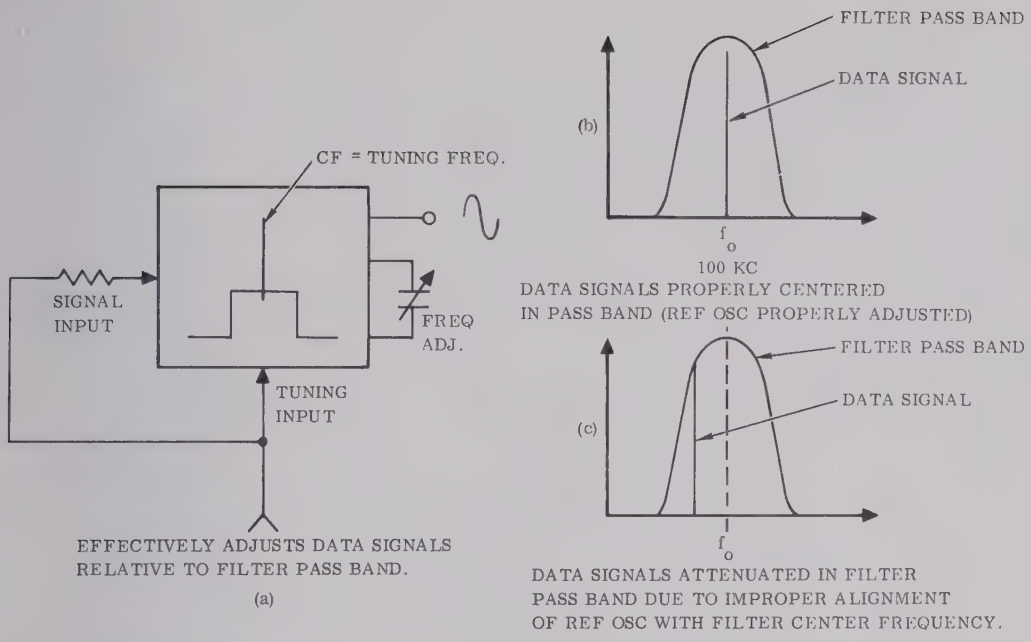


Figure 8. Alignment Procedure

inimum drift on a long-term basis is the reason for the oven-controlled crystal filters and en-controlled reference oscillator.

own in figure 9 is the practical circuit provided internally to not only adjust the center fre-ency of the filter, but apply a precise calibration reference signal to the input amplifier to t up and check the calibration of the instrument and any external readout devices.

hen the RANGE switch is placed in the CAL position, the external tuning signal and signal puts are disconnected from the unit. A portion of the 60 CPS filament voltage is fed into e tuning input and a 60 CPS square wave with a fundamental sine wave amplitude of 70 MV MS is applied to the input amplifier. Adjusting the FREQ control for a peak aligns the filter ith the tuning signal. Adjusting the GAIN for a meter reading of seven calibrates the unit.

-2. CIRCUIT DESCRIPTION.

thorough understanding of the general theory and concept of operation, along with the fol-owing circuit description will help in the application of the instrument, as well as the po-ential trouble-shooting of the instrument.

Filtering and Measurement Section

nge Switch (S1A, S1B)

he RANGE switch is a two-deck switch with two poles and six positions per deck. The in-t signal attenuator (SIA) is a one-megohm voltage divider with five positions for input sig-l attenuation ranges and the sixth position connects the 60 CPS reference voltage to the put amplifier. The second pole on SIA is used to disconnect the external tuning signal from e tuning signal input and apply an internal 60 CPS tuning signal. The second switch deck is ed to activate the calibration signal circuit. This switching is done to eliminate 60 CPS m from coupling into the input amplifier when the calibration circuits are not in use.

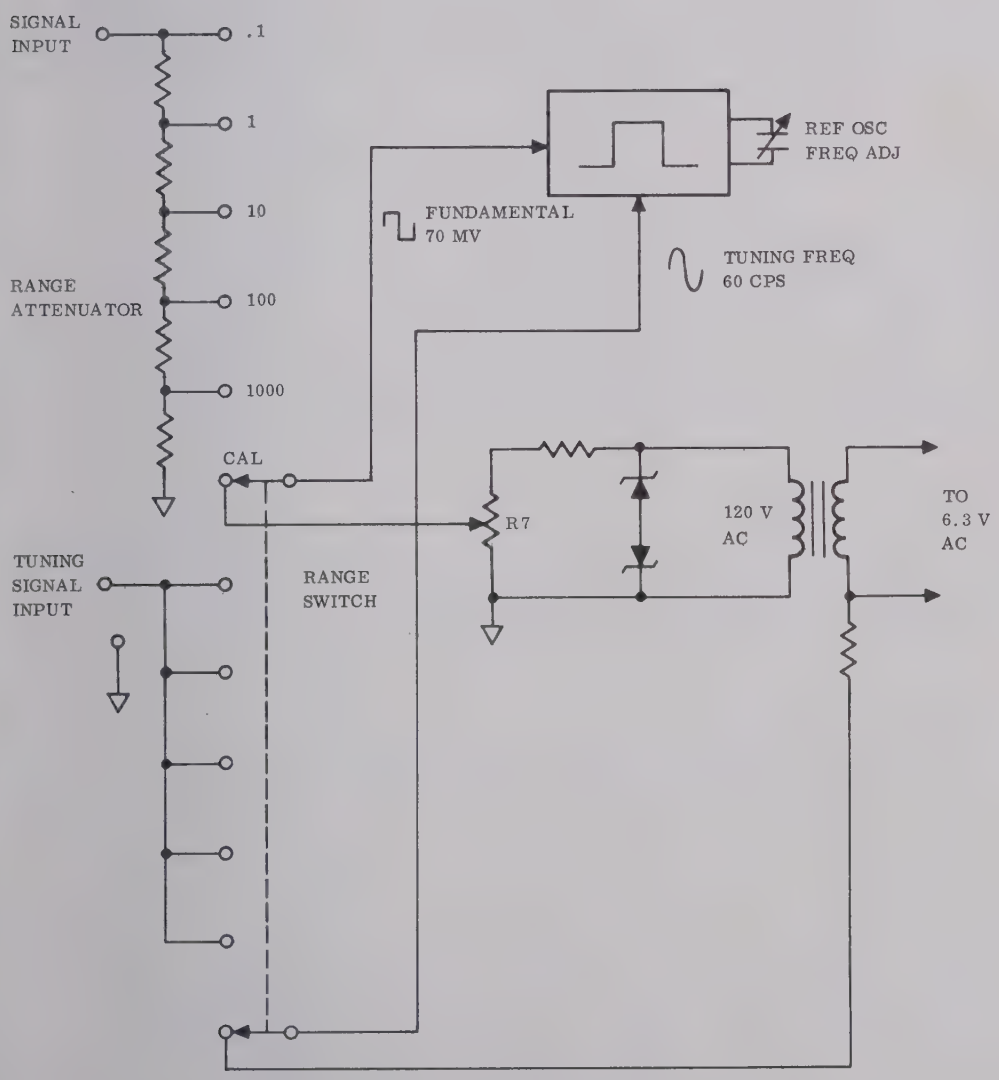


Figure 9. Internal Calibration

libration Circuit

libration circuit is made up of R6, R7, R8, R9, T1 and CR1. T1 is a filament transformer erated in reverse; i.e., the secondary is excited with 6.3V AC from the power supply ament source, thus producing 120 VAC at the primary. R8 is a current limiting resistor the back-to-back reference diode, CR1. CR1 clips the 120V signal to a reference level 12V peak-to-peak. R6 and R7 form a voltage divider to drop the 12V down to a 70 MV ndamental (equivalent sinusoidal amplitude). R7 is the CAL adjust potentiometer.

put Amplifier (V1, V2, V3)

e input amplifier is a two-stage voltage feedback amplifier with a cathode follower output oviding the driving signals to the signal modulator. The GAIN control varies the feedback ound the amplifier and is set up to give an adjustment range of 11 DB. CR14 is used to event blocking and provides rapid overload recovery. The input amplifier has a closed op gain of 100 and will handle crest factors (peak/RMS) of 4 to 1.

gnal Modulator (T2, C82, CR2A, R23, R24, R21)

he output of the input amplifier is connected to the signal modulator. The modulator is a unt-type carrier balanced modulator. The transformer is specially constructed to minimize reactive unbalance, and the diode pair (CR2A and B) are matched in characteristics to minimize carrier leak. C82 is an adjustment to allow further reactance balancing. The rimary of T2 is driven by V16, which is connected to the carrier converter output. The tput of the signal modulator will be a half wave suppressed carrier double sideband signal.

lter Driver (V4)

he output of the signal modulator goes to V4 which is a cathode follower used to provide impedance matching and isolation between the modulator and the crystal filters. A 3K resistor series with the input to the filter provides proper input termination for the filter.

lter Selector (S2A/B)

he FILTER selector switch is a two-position switch for selecting the desired filter bandidth. Both the input and output of the filters are switched to minimize the interaction beeen filters.

rystal Filters

he crystal filters are multi-section crystal lattice filters, providing extremely narrow kirts. The filters have a shape factor defined as the ratio of the 60 DB bandwidth divided y the 3 DB bandwidth of nominally 4/1. This shape factor is the same on all standard Spectral Dynamics' filters. Special bandwidths and shape factors can be supplied. The filters perate at a center frequency of 100 KC and require 3K resistive input and output termination.

inal sideband components falling within the filter bandwidth are passed through to potenmeters R28 and R29. R28 and R29 are used to equalize the relative insertion loss between filters in the SD-101 and additionally are used to establish the proper gain levels in the lowing amplifier stages. The 7.5K resistors shunting the potentiometers give proper load pedance to the crystal filters.

ned Amplifier (V6, V7)

is amplifier is used to remove spurious filter outputs and is a tuned, two-stage voltage dback amplifier. R39 is used to adjust the gain of the stage to approximately 250.

ultiplier

e output of the tuned amplifier is routed to a voltage divider, R230 and R231, with the dider output feeding the demodulator driver. The tuned amplifier output is also routed to e MULTIPLIER attenuator where the sensitivity of the meter and recorder circuits are ntrolled. The multiplier allows the meter to read levels 55 to 60 DB below a large input gnal component.

eter and Recorder Circuits

he output of the multiplier is connected to a nuvistor tetrode (V8) to minimize capacitive ading of the multiplier. The tetrode is the input stage of a two-stage voltage feedback amifier with a cathode follower output. The cathode follower drives the meter rectifier idge and a rectifier (CR6) providing the DC analog output. The 100 KC signal level at the thode follower output is approximately 20V peak-to-peak. Voltage feedback is derived om the cathode follower output for gain stabilization. R53 is the feedback resistor used adjust the amplifier for a nominal gain of 60.

ecorder Output

he output of CR6 is connected to a smoothing filter comprised of C22, R59 and C23, with e output of the smoothing filter connected to an output level adjustment, R60. The output resents a variable output impedance to a load and will provide at least 1V DC into a 10K ad for full-scale meter deflection. Since rectification of a 100 KC signal is accomplished, nort-time constant filtering is used giving the DC output rapid response with little ripple ven at low input frequencies.

emodulator-Demodulator Driver (V5)

he output of the tuned amplifier is connected via a voltage divider (R230 and R231) to V5 hich is a cathode follower used to drive one input of a ring demodulator. The other input the demodulator is supplied from the carrier converter coupled to the demodulator hrough V16.

carrier converter output frequency varies from 100,002 CPS to 125,000 CPS, corre-
ding to the tuning frequency input. The output from the tuned amplifier represents the
rodyned filtered signal and combined with the carrier converter frequency in the demodu-
r produces an output which is the sum and difference frequencies between the two signals
an amplitude proportional to the heterodyned filtered signal. The lower sideband or
frequency will be a signal that can vary in frequency from 2 CPS to 25 KC and the sum
ne two will be a frequency varying from 200,002 to 225,000 KC. The amplitude of the
al component is proportional to the filtered signal component.

demodulator output is then connected to a low pass filter network made up of L2, L3, L4,
, C36, C37 and C38, R82. The low pass filter is used to remove the upper sideband
ponent and has a nominal cutoff frequency of 30 KC, so that it will pass the signal com-
ents from 2 CPS as high as 30 KC with little attenuation and reject the high frequency
ponents from the modulator. The output of the low pass filter is then connected into the
ered signal output amplifier.

ered Signal Output Amplifier (V17, V18)

filtered signal output amplifier is a two-stage voltage feedback amplifier, with the plate
d potentiometer coupled to the filtered signal output terminals. The amplifier has the
ability of driving 10V RMS into a 100K load for full signal input. The output from the
te load potentiometer of V18 is coupled to the output terminals through C41, a 4 mfd.
acitor. When connecting loads to the output of the SD-101, it must be kept in mind that
t frequency response will be obtained with high impedance load. R86 sets the voltage
n of the amplifier to approximately 300.

Carrier Converter Section

e tuning signal is connected into the unit through a 100K potentiometer R90. The poten-
meter is used to adjust the level of the tuning signal for proper circuit operation. The
ing signal is then routed to the RANGE control switch to facilitate application of a fixed in-
nal tuning signal, making it unnecessary to disturb the setting of the tuning amplitude
ustment, during the calibration procedure. The tuning signal is next fed through the tun-
signal amplifier which isolates the external circuitry from the printed circuit board. The
put of the tuning signal amplifier, which is a simple resistance coupled amplifier having
ain of 20, is connected to the input stage of the wide band phase shifter.

de Band Phase Shifter

e wide band phase shifter consists of two printed circuit cards with the necessary tubes
d components mounted on it and identified as the upper and lower printed circuit card.
e cards are arbitrarily identified LOWER and UPPER for use as a guide for the mounting
d setting up of the cards.

e theory of operation can be described as follows: The phase shifter is made up of a com-
ation of half lattice all pass sections. The upper board produces a relatively smooth
se shift versus frequency curve and the lower board produces the same characteristic
se shift only displaced by 90° (figure 10).

e output of the boards will be two signals equal in amplitude but displaced by 90° over the
erating frequency range. A thorough treatment of the subject can be found in the following
erences:

1. D. Norgaard - The Phase-Shift Method of Single Sideband Signal Generation - Proc. IRE, December, 1956.
2. R. B. Dome - Wideband Phase Shift Networks - Electronics, VOL 19, Pages 112-115, December, 1946.

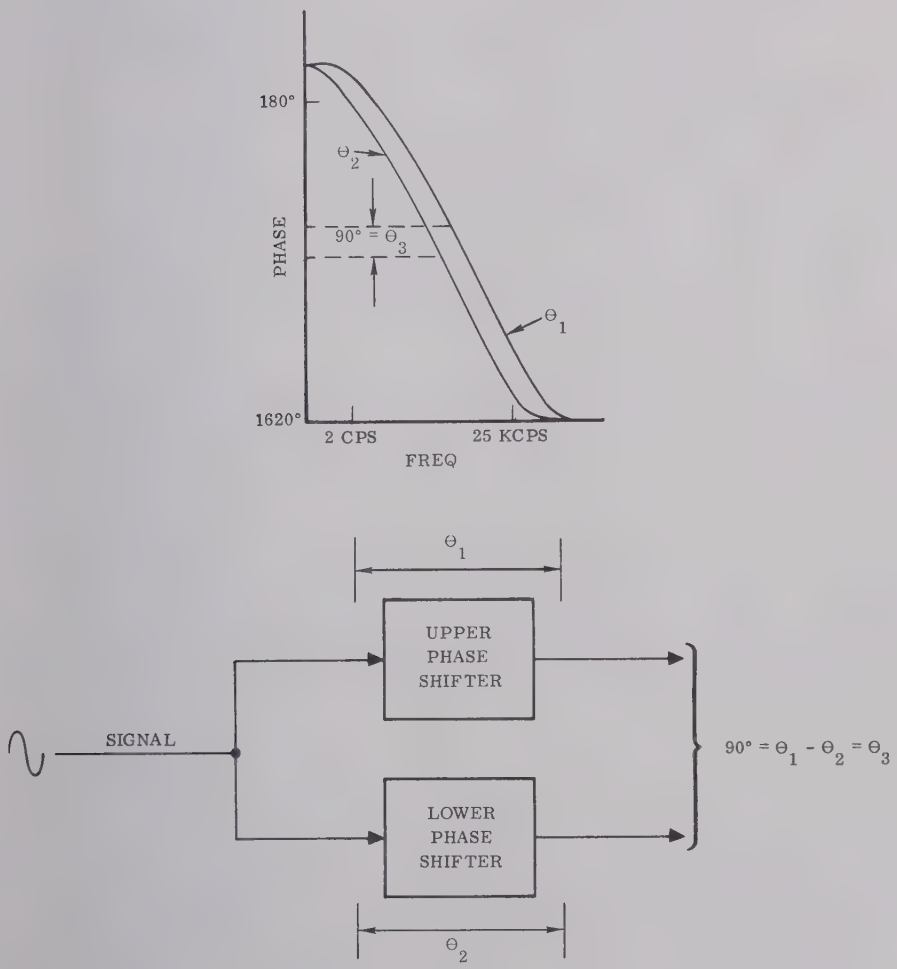


Figure 10. Wideband Phase Shifter

le outputs of the wideband phase shifter are connected to two modulators.

rrier Modulators

e two carrier modulators are identical to the signal modulator described earlier. The rrier signals are applied to the modulators from the reference oscillator circuits. The ference oscillator circuits drive the modulators with 100 KC signals that are shifted 90°. e output of the modulators are then linearily summed in R199, Carrier amplitude balance justment.

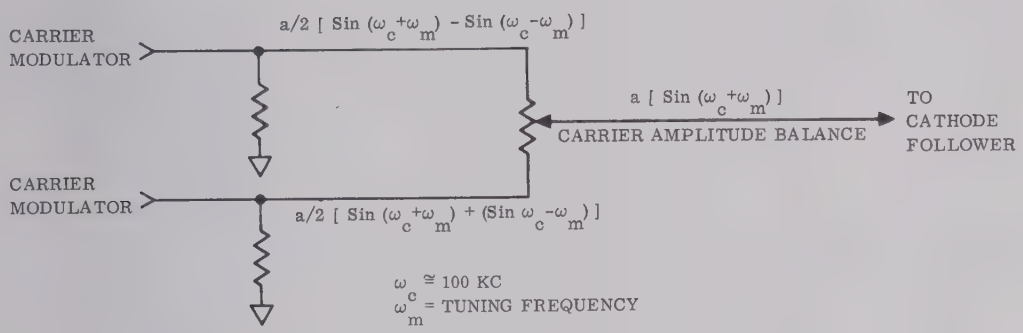

CARRIER MODULATOR
a/2 [Sin (ωc+ωm) - Sin (ωc-ωm)]
a [Sin (ωc+ωm)]
CARRIER AMPLITUDE BALANCE
TO CATHODE FOLLOWER
CARRIER MODULATOR
a/2 [Sin (ωc+ωm) + (Sin ωc-ωm)]
ωc ≅ 100 KC
ωm = TUNING FREQUENCY
ADDITION OF MODULATOR OUTPUTS TO GIVE UPPER SIDEBAND

Figure 11. Upper Sideband

he addition of the two signals results in the upper sideband amplitude adding together and e lower sideband amplitudes adding out (figure 11).

andpass Filter (100 - 150 KC)

he output of the adjusting potentiometer R199 is connected to V40 which is a cathode fol- wer amplifier used to drive a bandpass filter. The bandpass filter is used to remove purious modulation components and provide a clean upper sideband signal to the carrier mplifier.

arrier Amplifier (V41, V42)

he carrier amplifier amplifies the upper sideband signal to a suitable level for driving the gnal modulator and demodulator. The output of the carrier amplifier is routed to the Ex- rnal, Internal Carrier switch. With the EXT/INT switch in the INT position, the carrier mplifier output is connected to the signal modulator/demodulator driver (V16). With the witch in the EXT position, the B+ supplied to the carrier converter section is disconnected nd an external carrier signal can be connected into the connector marked EXT CARRIER NPUT. Driving the modulators from an external source is desirable when using two or ore SD-101's slaved together.

ference Oscillator-Phase Shifter-Carrier Modulator Drivers

e reference oscillator consists of V11, V12 and the plug-in reference oscillator crystal d oven. The oscillator is a Pierce-type. The frequency control C28, is used to adjust e frequency of the reference oscillator over a range of approximately ±15 CPS. The sta- ity of the oscillator is ±.25 CPS and is maintained over long periods of time due to the en-controlled crystal.

e output amplitude of the oscillator is controlled by C25 and C90. The oscillator output connected to V14. V14 is a paraphase phase-shift amplifier with the phase shift deter- ned by the R.C. half lattice output network. The lattice output is connected to a modulator iver, V15. The R.C. combination, adjustable with R73, is adjusted to produce a 90° ase shift between the output of V13 and the output of V15. The signal appearing across R72 used to drive V13.

wer Supply

7.5 mV @ 150 VDC

e power supply module provides 100 milliamps at 125 to 175 VDC, with ripple of .3 MV d regulation of .005%. With the POWER switch on STBY the filament voltage is applied to e tubes and heater voltage is applied to the filter and oscillator ovens.

e power supplied to the crystal filter heaters is rectified DC from the 60 CPS line, with arc suppression capacitor connected across each filter heater contact (C84, C83).

SECTION IV

MAINTENANCE

1. GENERAL.

e various assemblies in the analyzer, with major circuit locations are shown in figures and 13. Viewing the bottom of the analyzer it is seen that the unit is comprised of four jor assemblies which are designated: (1) Low Frequency; (2) High Frequency; (3) Car- r Converter; (4) Power Supply. The wideband phase shift networks are plug-in assem- es and are shown in figure 12, Item 4. The general location of specific circuits may be nd by referring to figures 12 and 13.

2. TEST POINTS.

en trouble shooting and aligning the SD-101 there are test points referenced on the ock Diagram and Schematic. These test points may be physically located by referring to ure 14. Waveforms and voltage levels at each corresponding test point are shown in the er part of this section.

3. REPAIR AND MAINTENANCE.

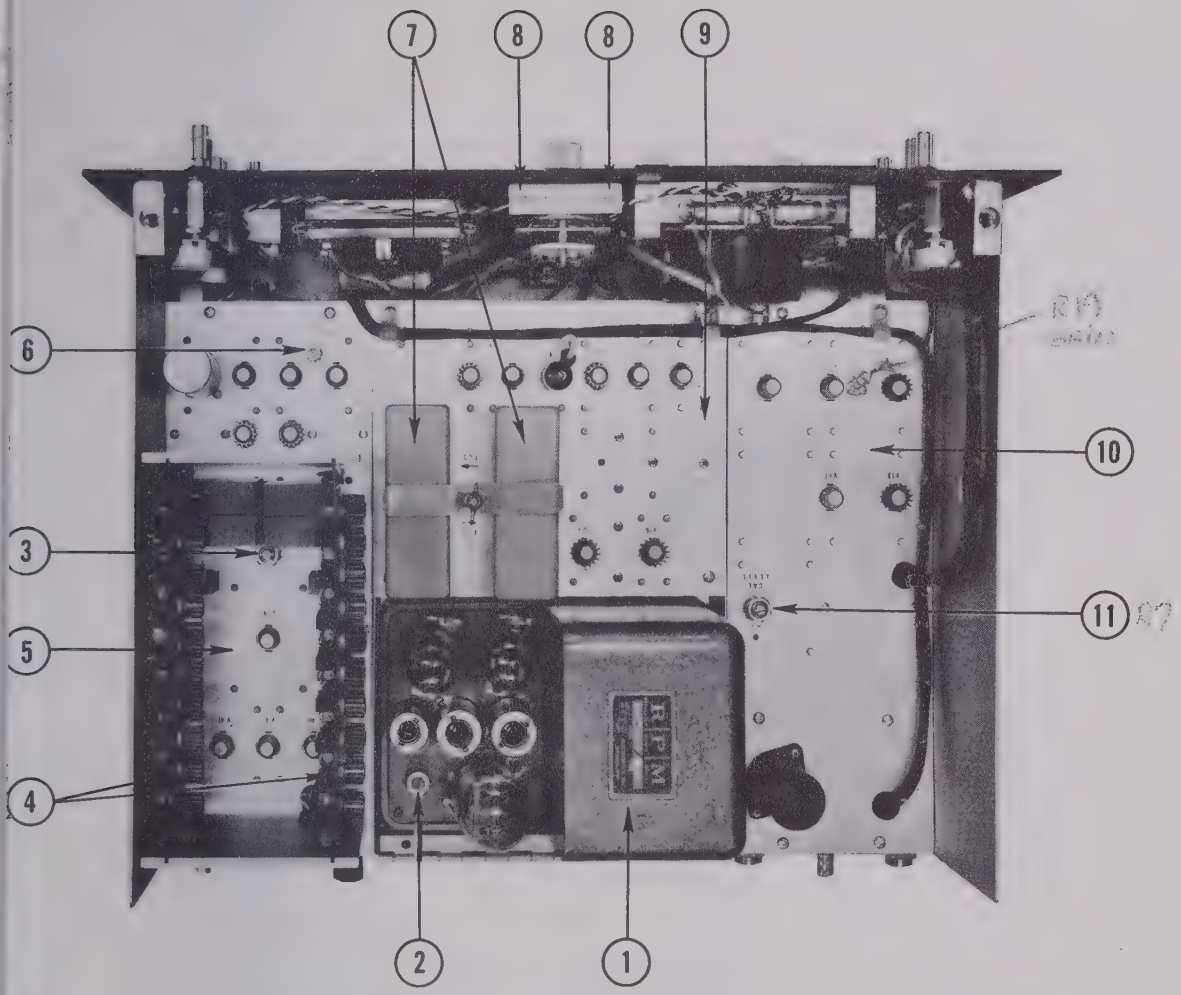
pair and Maintenance of all circuits can be accomplished by the user with the following eptions:

1. Wideband Phase Shifters (figures 15 and 16)

Repair by the user of the circuits on the plug-in printed circuit boards should limited to replacement of tubes, repair of broken leads and replacement of any of the 1 watt, 5%, 1000 Ω resistors. Do not disturb the factory adjustments or precision compo- nts. If boards are in need of recalibration and adjustments (Ref. Item 5b Trouble Shoot- Guide) they should be returned to the factory. Return of items to the factory is governed the paragraphs Warranty and Shipping found in the preface of this manual.

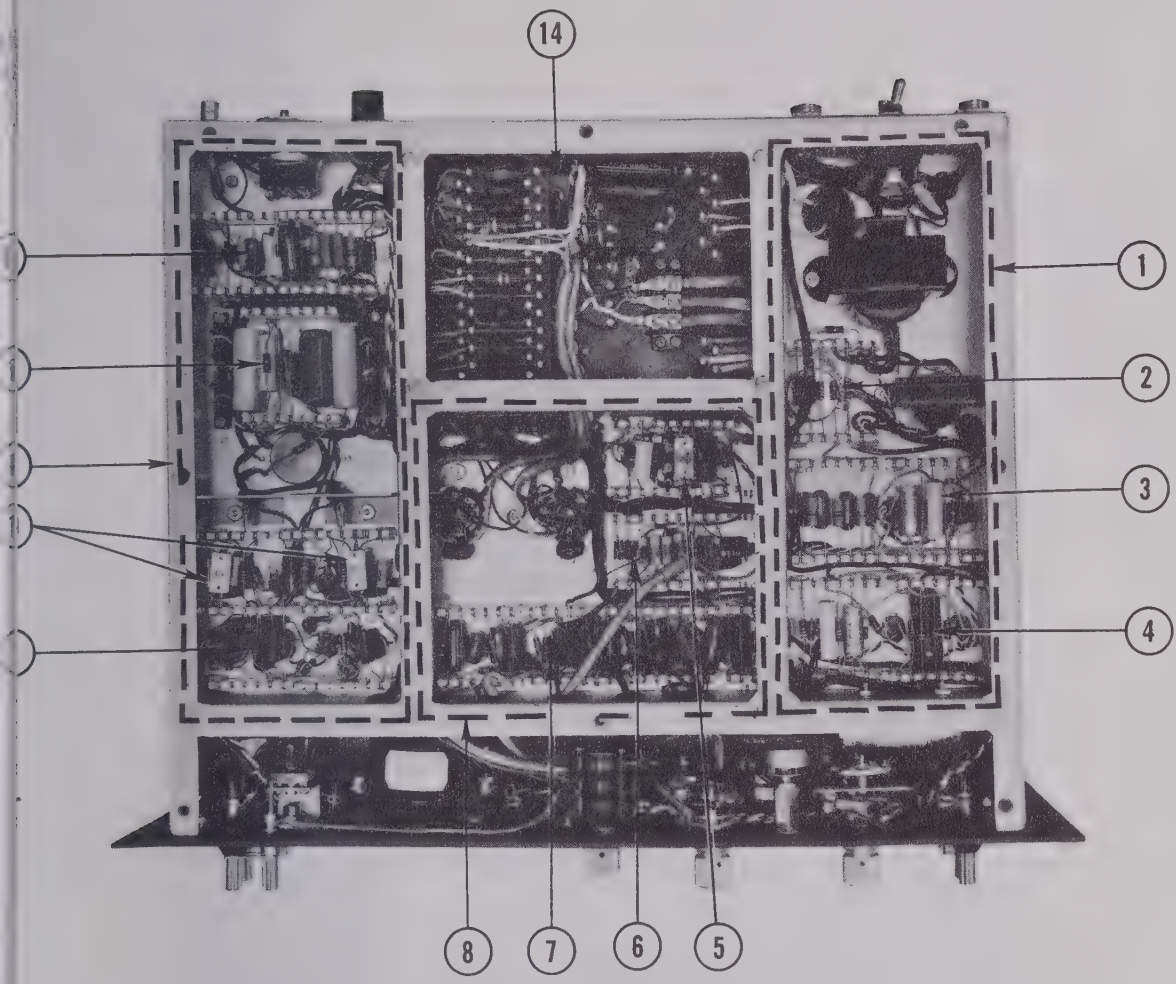
2. Crystal Filters

Due to the complexity of the crystal filters, repair should be performed only the factory. Normally, the filters will perform indefinitely without maintenance or re- ir. The most common failure encountered is the malfunction of the thermostat controlling e oven heater. Thermostat failure is indicated by excessive shift in center frequency owing up as an apparent change in SD-101 gain. Insertion loss of the filters becomes very gh. Occasionally, a filter will be dropped or mishandled which can result in damage to the ystals. If a filter requires repair return it to the factory along with a statement of the



1 POWER SUPPLY MODULE
2 B+ LEVEL ADJUSTMENT
3 CARRIER AMPLITUDE BALANCE
4 WIDEBAND PHASE SHIFTER PRINTED CIRCUIT CARDS
5 CARRIER CONVERTER SECTION
6 REFERENCE OSCILLATOR PHASE ADJUST
7 PLUG IN CRYSTAL FILTERS
8 NORMALIZING POTS FOR CRYSTAL FILTERS
9 HIGH FREQUENCY SECTION
10 LOW FREQUENCY SECTION
11 REFERENCE CALIBRATION LEVEL ADJUST

Figure 12. Top View



1 LOW FREQUENCY SECTION
2 CALIBRATION CIRCUIT
3 FILTERED SIGNAL OUTPUT CIRCUIT
4 INPUT AMPLIFIER
5 SIGNAL MODULATOR BALANCE
6 DEMODULATOR CIRCUIT
7 TUNED AMPLIFIER, METER AMPLIFIER
8 HIGH FREQUENCY SECTION
9 REFERENCE OSCILLATOR
10 CARRIER MODULATOR BALANCE
11 TUNING SIGNAL INPUT AMPLIFIER
12 CARRIER SIDEBAND AMPLIFIER AND FILTER
13 CARRIER CONVERTER SECTION
14 POWER SUPPLY MODULE

Figure 13. Bottom View

(17) PRINTED CIRCUIT BOARD (SEE FIGURE 15)

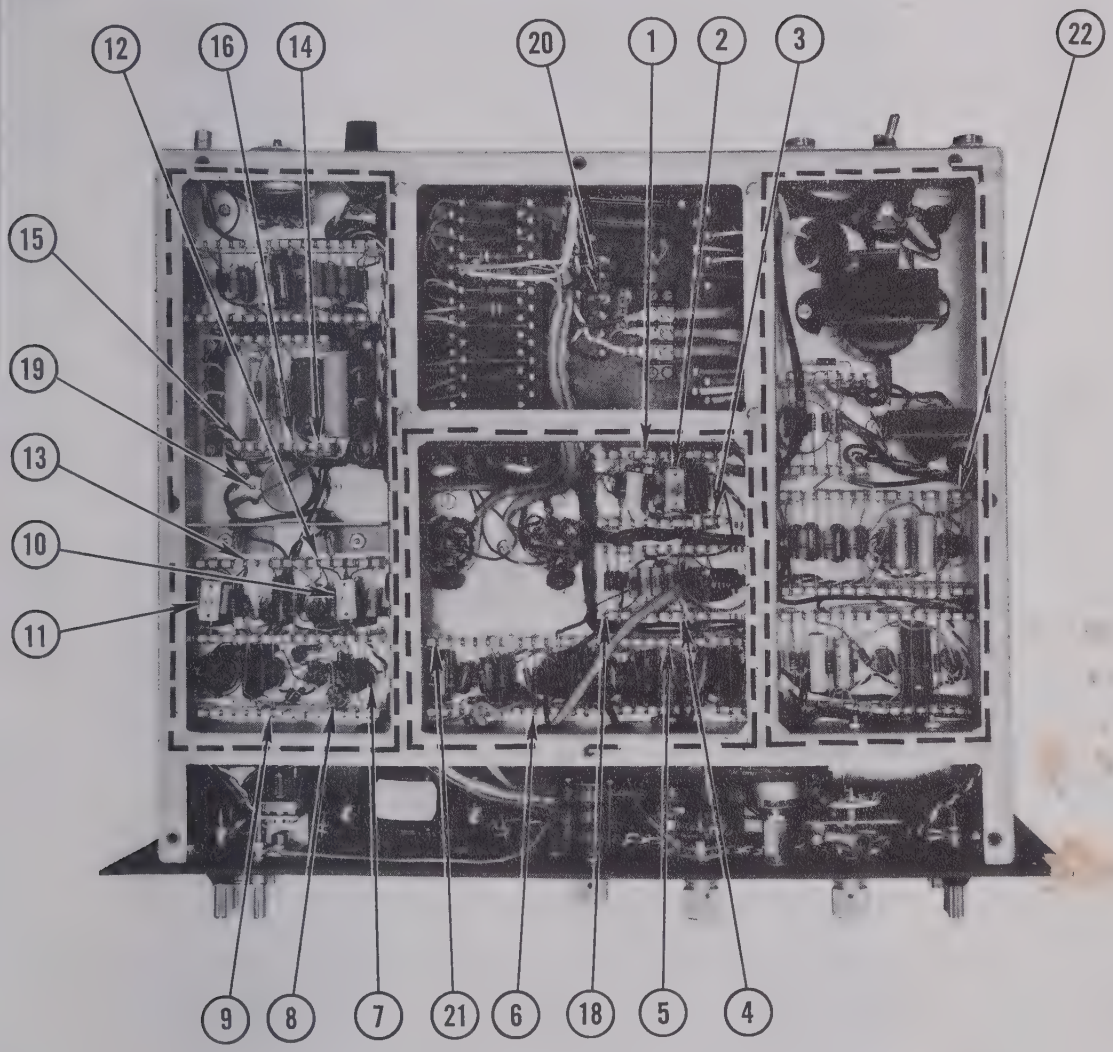


Figure 14. Test Points and Internal Adjustment Locations

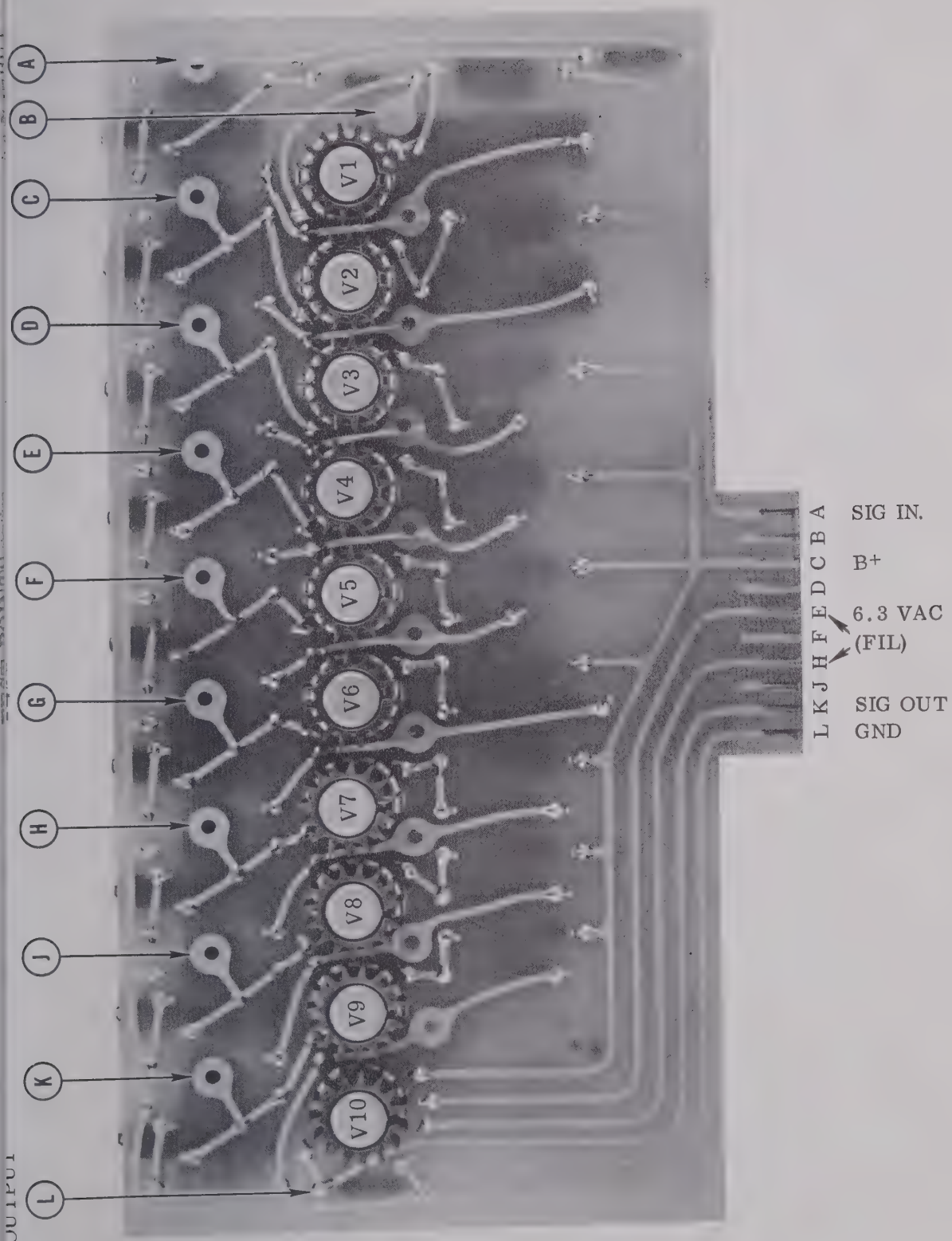


Figure 15. Wideband Phase Shift Circuit Board - Layout and Test Points

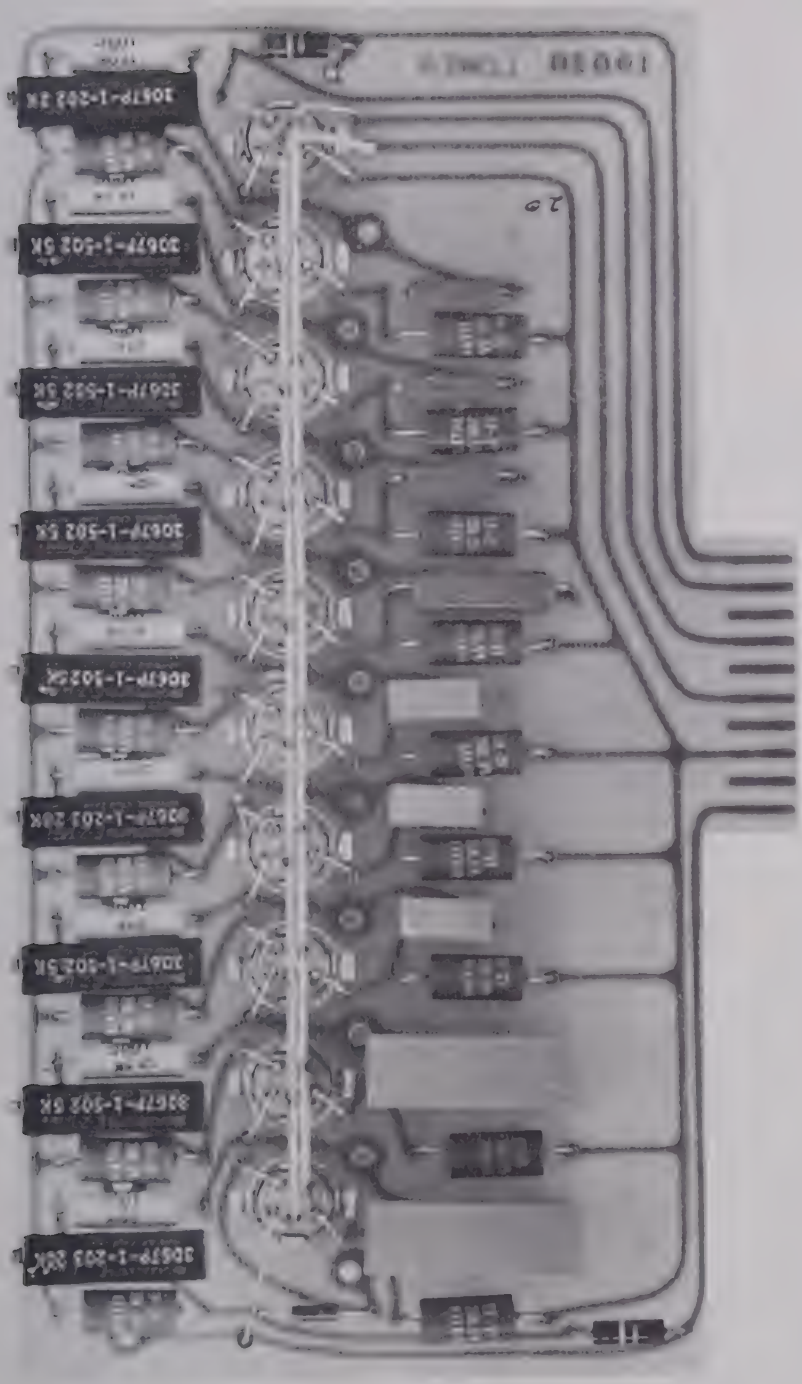


Figure 16. Printed Circuit Board (Component Side)

parent difficulty. Return of items to factory is governed by paragraphs Warranty and pping in the Preface of this manual.

4. TROUBLE SHOOTING.

a malfunction of the analyzer occurs, refer to the Trouble Shooting Guide in this section. is guide lists probable causes and remedies for improper operation. Make certain that me external situation is not influencing the operation of the unit and that the unit is being erated properly. Look for simple causes. The SD-101 is ruggedly constructed with con- rvative ratings on components. The SD-101 should require a minimum of adjustment and pair and provide long trouble-free service.

5. MAINTENANCE ADJUSTMENTS.

e following are maintenance checks and adjustments that should be performed periodically deemed necessary by the users routine calibration cycle. An initial recheck and adjust- nt of the instrument should be performed after approximately the first 200 hours of eration.

6. FREQUENCY RESPONSE.

1. Place the instrument in operation in the normal manner.

2. Holding the input level constant, slowly scan the frequency range noting analyzer ter and filtered signal output level deviations. The frequency response as indicated by meter should be within ±1/4 DB from a frequency equal to 1/2 the filter bandwidth to

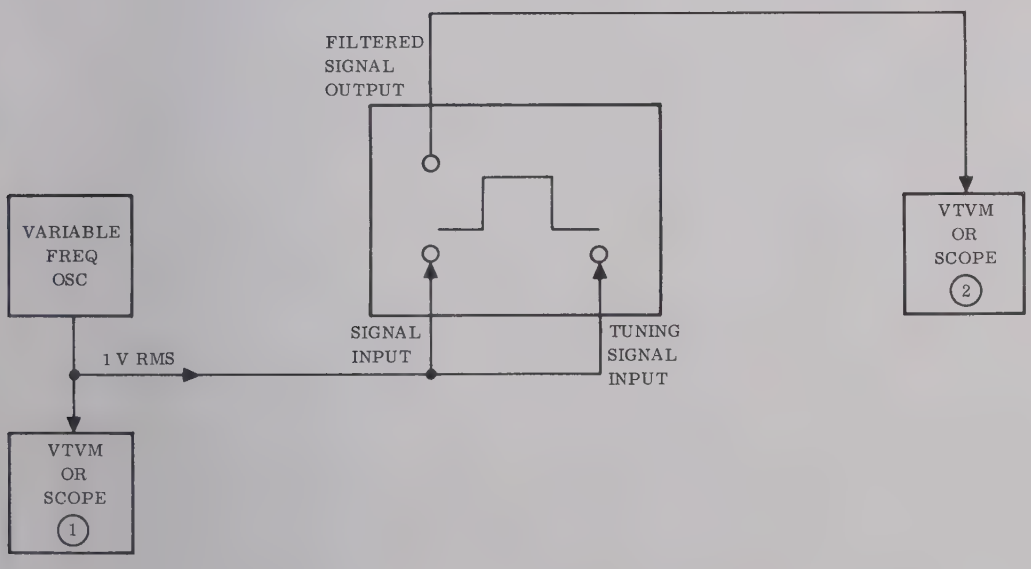


Figure 17. Test Setup #1

5 KC. The filtered signal output response should be ±0.25 DB from a frequency equal to /2 the filter bandwidth to 5 KC and falls off gradually above 5 KC until it is down approxiately 1.25 DB at 25 KC. Excessive deviations from this characteristic indicate the wideand phase shifter is in need of factory adjustment or the carrier converter needs alignent (Paragraph 4-8).

-7. SIGNAL MODULATOR BALANCE.

o balance the signal modulator use the same test setup as in 4-6. Disconnect the signal nput and short circuit the signal input terminals. Set the MULTIPLIER on .01 and adjust ne tuning frequency to below 1/2 the bandwidth of the filter and for a maximum meter deection. Adjust the signal modulator balance control (#5, figure 13) for a null. This completes the procedure. There will be a slight fluctuation of the balance but the level of this ignal is so low that it should not influence the data at frequencies higher than 1/2 the filter andwidth.

-8. CARRIER CONVERTER SIDEBAND OUTPUT ALIGNMENT.

arrier converter alignment is required when any of the wideband phase shift networks are epaired or replaced (with the exception of tube replacement), if V14 is replaced and as a eriodic maintenance adjustment.

he procedure is used to obtain optimum internal adjustment for lower sideband rejection. he alignment is performed using the following internal adjustments:

arrier modulators balance controls (#10, figure 13); Oscillator Phase adjust (#6, figure 2); and the Carrier Amplitude balance (#3, figure 12). The adjustments should be perprmed using a narrow filter (20 CPS or less).

1. Place the RANGE and MULTIPLIER controls on CAL and calibrate the instruent in the normal manner (Paragraph 2-2).

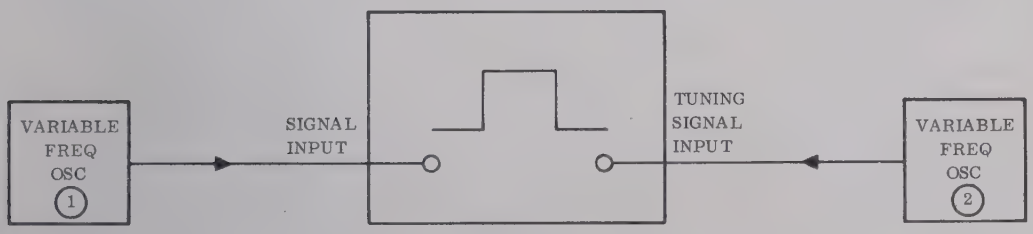


Figure 18. Test Setup #2

2. Rotate the FREQUENCY control until a meter reading of around 3 on the 0-10 ale is obtained.

3. Place the RANGE on 1V and the MULTIPLIER on 1.0.

4. Adjust the tuning frequency from Oscillator 2 to 100 CPS and adjust the Oscil- or 2 output level for a center line tuning meter deflection.

5. Adjust the signal input frequency from Oscillator 1 to approximately 100 CPS d search for a meter deflection on the large meter. Adjust the signal level from Oscil- or 1 for full-scale meter deflection.

6. Note the signal input frequency.

7. Adjust the TUNING input frequency to 1/2 the signal frequency and rotate the ultiplier counterclockwise until a meter deflection is noticed.

8. Search with the TUNING frequency for a peak meter deflection.

9. Adjust both Carrier Modulator BALANCE controls for a null with the Multiplier the .01 position.

10. Adjust the TUNING frequency to 1/3 the signal frequency and search for a peak eter deflection.

11. Adjust the Carrier Amplitude BALANCE and Oscillator PHASE ADJ. alternately r a null.

12. Repeat Steps 7, 8, 9, 10 and 11 until the best null for both conditions is obtained.

13. Return the RANGE and MULTIPLIER to CAL; repeak the FREQUENCY adjustmen

14. Alignment completed.

road filters can be used if the tuning frequency is first set to a higher frequency, say 300 PS instead of 100 CPS. The alignment procedure would be the same. The 100 CPS was rimarily chosen to reduce the sensitivity of the external oscillator frequency adjustment hen using very narrow filters for performing the alignment.

-9. GAIN. (USE PROCEDURE [illegible])

hen performing routine maintenance on the unit it is necessary to adjust the gain of the ignal amplifier for 100.

he gain of this amplifier is considered the ratio of the signal amplitude measured at test oint 1 (#1, figure 14) and the input signal amplitude with the RANGE control set on . 1V.

s adjustment provides the proper gain reference for the remainder of the circuitry; i.e., n through filters, insertion loss pots, tuned amplifier, demodulator, and meter circuit.

er setting the gain of the signal amplifier, the insertion loss potentiometers associated h the filters should be adjusted. For location of these potentiometers refer to #8, figure The adjustment is made with one volt (RMS) signal applied to the signal and tuning sig- inputs. The tuning signal level must be adjusted until the tuning signal meter reads in center of the red range. Set the RANGE switch at 1.0 volt, rotate the FREQUENCY ad- tment on the front panel to align the 100 KC reference oscillator to the center frequency the filter being normalized. Center frequency alignment is indicated by a peak meter de- ction. Adjust the associated potentiometer for each filter, for a meter reading of 10-- s corresponds to the input signal voltage of one volt (RMS).

10. CALIBRATION OF INTERNAL CAL REFERENCE.

re-calibrate the instruments internal reference against a standard voltmeter, the fol- ving procedure is used:

1. Set the RANGE at 1V and the MULTIPLIER at 1.0 and select narrowest filter unit.

2. Connect an external signal of 1V RMS from an oscillator to both the SIGNAL PUT and TUNING INPUT. Adjust the Tuning Signal Meter for a center line indication.

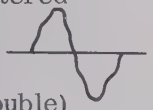
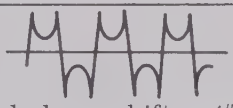
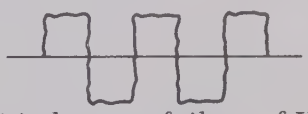
3. Adjust the FREQUENCY control for a peak indication on the output meter.

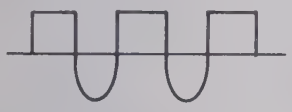
4. Adjust the GAIN control for a gain of 100 in signal amplifier and the filter nor- alizing potentiometers for a full-scale meter indication. Refer to paragraph 4-9 for the tailed procedure.

5. Switch the RANGE and MULTIPLIER to CAL and the meter should indicate 7. not, open the top cover of the instrument and adjust the potentiometer marked R7 CAL DJ located on the top left side of the chassis until a meter reading of 7 is obtained. Repeat e procedure to be sure of proper adjustment and lock CAL ADJ potentiometer, observing e meter reading with the RANGE and MULTIPLIER switches in CAL to make sure this ading does not change when re-locking potentiometer.

11. TROUBLE SHOOTING GUIDE.

SYMPTOM	PROBABLE CAUSE AND REMEDY
1. No Power	Blown fuse. Replace with 2 AMP, 3AG slo-blow. If this fails, remove bottom cover and check for possible short circuit in B+ lead. B+ leads are all the red leads, with exception of leads from the transformers.

SYMPTOM	PROBABLE CAUSE AND REMEDY
2. Distortion of Filtered Signal Output --  (Operational Trouble)	(a) Tuning signal level too low or high. Readjust to center line on tuning amplitude meter. (b) Distortion or noise in tuning signal - Clean up tuning signal waveform. (c) Filter bandwidth too wide for frequency of operation. (d) Input signal level to analyzer too high, overloading input amplifier - Change RANGE switch to higher position.
3. Distortion of Filtered Signal Output - (Equipment malfunction or misalignment) 3a. Unable to calibrate unit having insufficient gain 3b. Tuning Meter comes barely into red band when unit is on CAL	(a) Output waveform  tube failure in wideband phase shifter (#4, figure 12) - Check for sine wave along circuit boards (Test points shown in figure 15.) (b) Output waveform  Trouble same as (a) above or failure of V13 or V15 - Check for sine wave along circuit boards if sine wave present from all stages replace V13 or V15.
4. Excessive noise in filtered signal output	(a) Range Switch in wrong position - Not utilizing full dynamic range of instrument (b) Noise on power line (c) V17 or V18 is noisy - Replace (d) Demodulator unbalanced or defective diode (CR 3A through D) (e) Defective or noisy power supply regulator tube V46, V47, V48
5. Frequency Response falls off at low frequency	Load impedance on filtered output too low - Increase to 100K

SYMPTOM	PROBABLE CAUSE AND REMEDY
a. Frequency Response rises at low frequency	(a) Capacitor lead on wideband phase shifter broken, open resistor - Repair or return boards to factory for repair (b) Signal modulator unbalanced - Balance per Paragraph 4-7
b. Frequency Response generally poor at all frequencies with dips and peaks in response	(a) Wideband phase shifter needs recalibration - or broken lead on resistor or capacitor in wideband phase shifter (b) Carrier converter needs realignment. (Ref. Paragraph 4-8.)
5. Low Meter deflection on CAL and filtered signal output provides approximately 50 MV output max. and is clipped on one side 	C11 shorted, replace with 560 PFD., 200V capacitor
7. No meter deflection or recorder output, filtered signal output OK	(a) V8, V9, or V10 defective - Replace (b) C16 shorted - Replace with 560 PFD, 200V
8. No tuning Meter indication, no meter deflection, unit appears inoperative; power lights on	(a) Carrier Int. - Ext. Switch in wrong position (b) V11, V12, V14, V40, V41, V42, V16, or V19 defective
Note Symptoms of 6, 7, and 8 appear with unit in normal operation or in CAL.	
9. No CAL signals, equipment works satisfactorily otherwise	(a) Failure of T1 (b) Broken wire in CAL circuit (c) R7 set wrong

SYMPTOM	PROBABLE CAUSE AND REMEDY
Low sensitivity after unit warms up - Unable to calibrate unit - large gain drift	Filter overheating due to defective thermostat

2. TROUBLE SHOOTING - GENERAL.

he above suggestions fail to correct the difficulty then refer to the various test points ss referenced between the block diagram, schematic, figures 14 and 15, and Paragraph 3. Paragraph 4-13 lists the test points and illustrates the waveforms and signal voltage ls that should be present.

3. TEST POINTS AND ASSOCIATED WAVEFORMS AND SIGNAL VOLTAGE LEVELS.

following test points, waveforms and voltage levels were determined under the condi-s below:

. Test Setup:

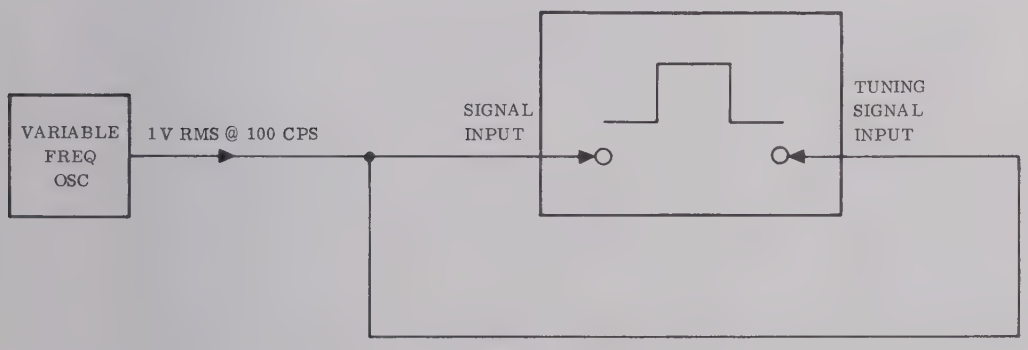
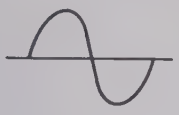
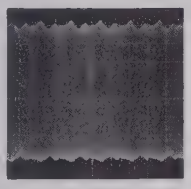
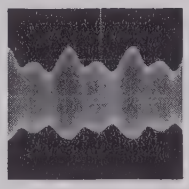


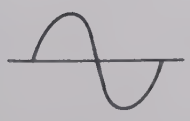
Figure 19. Test Setup #3

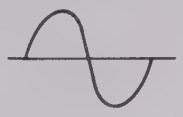
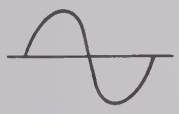
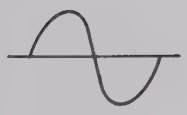
Voltage and waveforms were measured on a Tektronix #561 Oscilloscope using a 10-egohm probe.

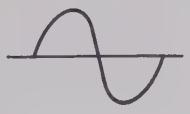
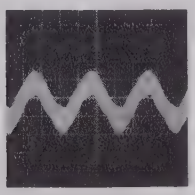
Audio frequency amplitude measurements were obtained with a Ballantine #320 VTVM ere applicable.

RANGE and MULTIPLIER set on 1V and 1.0, respectively, and unit aligned per Paragraph 2-1.

TEST POINT	WAVEFORM	VOLTAGE LEVEL
Signal Frequency	 Sinewave	Adjust GAIN for 28-30V p-p
Signal Modulator Balance	(Refer to figure 14 for location.)	Refer to paragraph 4-7 for alignment procedure
Upper sideband signal test point used for checking carrier converter alignment	 Carrier Converter properly adjusted  Carrier Converter improperly adjusted	60-70V p-p for center scale tuning meter indication
Demodulator Output Suppressed Carrier Signal		.2V p-p approx.
Tuned Amplifier Output	100 KC sinewave	30V p-p approx.
Meter Amplifier	100 KC slightly distorted sinewave	20V p-p approx.

TEST POINT	WAVEFORM	VOLTAGE LEVEL
Oscillator Amplitude Control - Controls amplitude of signal appearing at Test Point (9)	Referenced for location	Early units had a fixed capacitor
Oscillator Phase Control - Used for aligning carrier converter - Referenced for location		
Reference Oscillator Output	100 KC sinewave	Adjust for 35-40V p-p
Carrier Modulator Balance Controls - Referenced for location		
Carrier Modulator Drive Signal	100 KC sinewave	35-40V p-p and approx. equal to amplitude at Test Point (13)
Carrier Modulator Drive Signal	100 KC sinewave	35-40V p-p (12) and (13) should be approx. 90° phase difference. The phase shift is adjusted properly when performing alignment procedure (Paragraph 4-8)
Output of Upper Printed Circuit Board	 Tuning Signal Frequency Sinewave	6-8V p-p

TEST POINT	WAVEFORM	VOLTAGE LEVEL
Output of Lower Printed Circuit Board	 Tuning Signal Frequency Sinewave	6-8V p-p - Test Points (14) and (15) will be approx. equal in amplitude and 90° out of phase
Output of Tuning Signal Amplifier	 Tuning Signal Frequency Sinewave	Approx. 12V p-p
Wideband Phase Shifter Printed Circuit Cards Test Points (A) through (L) on each card. Ref. figure 15 and schematic		
(A) Signal Input	 Tuning Signal Frequency Sinewave	Approx. 12V p-p for centerline on tuning meter
(B)-(C)-(D)-(E)-(F)-(G)-(H)-(J)-(K) Cathodes of Paraphase Amplifiers	Tuning Signal Frequency Sinewave	A loss of approx. .6V/stage The gain of each stage ≅ .95

TEST POINT	WAVEFORM	VOLTAGE LEVEL
(Continued)		
(L) Output		-6-8V p-p
	Tuning Signal Frequency Sinewave	
Filter Input		4V p-p
	Modulated Signal Frequency	
Output of Carrier Amplitude Balance Network (unfiltered upper sideband)		1V - 1.5V p-p
B+ from Power Supply		150V DC
Recorder Circuit		1.3 - 1.8V DC with recorder output adj. full clockwise
Filtered Signal		32 - 36V p-p with filtered signal output adj. full clockwise
	Signal Frequency Sinewave	

SECTION V

TABLE OF REPLACEABLE PARTS

1 GENERAL.

dard components have been used in this instrument, whenever possible. Special compo-
s may be obtained direct from the factory. Orders for components should include a
plete description of the part, along with model and serial numbers of the instrument.

following table lists the replaceable components, complete with reference designation.

Table 5-1. Replaceable Parts

REFERENCE DESIGNATION	DESCRIPTION	PART NUMBER
R1	Resistor, 909K, 1/4W, .5%	20002-500
R2	Resistor, 90.9K, 1/4W, .5%	20002-501
R3	Resistor, 9.09K, 1/4W, .5%	20002-502
R4	Resistor, 909 ohm, 1/4W, .5%	20002-503
R5	Resistor, 101 ohm, 1/4W, .5%	20002-504
R6	Resistor, 33K, 1/2W, 5%	20000-001
R7	Resistor, 1K, 2W, 5%, W.W.	20002-001
R8	Resistor, 12K, 1W, 5%	20001-500
R9	Resistor, 1 Meg., 1/2W, 5%	20000-002
R10	Resistor, 56K, 1/2W, 5%	20000-003
R11	Resistor, 1K, 1/4W, 5%	20000-001
R12	Resistor, 1 Meg. 1/2W, 5%	20000-002
R13	Resistor, 100K, 1/2W, 5%	20000-004
R14	Resistor, 56K, 1/2W, 5%	20000-003
R15	Resistor, 1K, 1/4W, 5%	20001-001
R16	Resistor, 39K, 1/2W, 5%	20000-045
R17	Resistor, 270K, 1/2W, 5%	20000-006
R18	Resistor, 270 ohm, 1/2W, 5%	20000-007
R19	Potentiometer, 10K, 2W, 10%	20009-002
R20	Resistor, 3.9K, 1/2W, 5%	20000-008
R21	Resistor, 100K, 1/2W, 5%	20000-004
R22	Resistor, 20K, 1/2W, 5%	20000-009
R23	Resistor, 500 ohm, 1/4W, .5%	20002-505
R24	Resistor, 500 ohm, 1/4W, .5%	20002-505

Table 5-1. Replaceable Parts (Continued)

REFERENCE DESIGNATION	DESCRIPTION	PART NUMBER
R25	Resistor, 270K, 1/2W, 5%	20000-006
R26	Resistor, 270 ohm, 1/2W, 5%	20000-007
R27	Resistor, 15K, 1/2W, 5%	20000-010
R28	Potentiometer, 5K, 3/4W	20009-003
R29	Potentiometer, 5K, 3/4W	20009-003
R30	Resistor, 500 ohm, 1/4W, .5%	20002-505
R31	Resistor, 500 ohm, 1/4W, .5%	20002-505
R32	Resistor, 500 ohm, 1/4W, .5%	20002-505
R33	Resistor, 500 ohm, 1/4W, .5%	20002-505
R34	Resistor, 270K, 1/2W, 5%	20000-006
R35	Resistor, 270 ohm, 1/2W, 5%	20000-007
R36	Resistor, 56K, 1/2W, 5%	20000-003
R37	Resistor, 820 ohm, 1/2W, 5%	20000-011
R38	Resistor, 220 ohm, 1/2W, 5%	20000-012
R39	Resistor, Factory Adjustment	-----
R40	Resistor, 270K, 1/2W, 5%	20000-006
R41	Resistor, 1K, 1/4W, 5%	20001-001
R42	Resistor, 15K, 1/2W, 5%	20000-010
R43	Resistor, 110K, 1/4W, .5%	20002-506
R44	Resistor, 34.8K, 1/4W, .5%	20002-507
R45	Resistor, 11K, 1/4W, .5%	20002-508
R46	Resistor, 3.48K, 1/4W, .5%	20002-509
R47	Resistor, 1.609K, 1/4W, .5%	20002-510
R48	Resistor, 22K, 1/2W, 5%	20000-034
R49	Resistor, 1K, 1/4W, 5%	20001-001
R50	Resistor, 56K, 1/2W, 5%	20000-003
R51	Resistor, 270K, 1/2W, 5%	20000-006
R52	Resistor, 1K, 1/4W, 5%	20001-001
R53	Resistor, Factory Adjustment	-----
R54	Resistor, 82K, 1/2W, 5%	20000-028
R55	Resistor, 270K, 1/2W, 5%	20000-006
R56	Resistor, 100 ohm, 1/2W, 5%	20000-014
R57	Resistor, 4.7K, 1/2W, 5%	20000-015
R58	Resistor, 2.7K, 1/2W, 5%	20000-016
R59	Resistor, 4.7K, 1/2W, 5%	20000-015
R60	Potentiometer, 2.5K, 2W, 10%	20009-012
R61	Resistor, 330K, 1/2W, 5%	20000-017
R62	Resistor, 68K, 1/2W, 5%	20000-031
R63	Resistor, 56K, 1/2W, 5%	20000-003

Table 5-1. Replaceable Parts (Continued)

REFERENCE DESIGNATION	DESCRIPTION	PART NUMBER
R64	Resistor, 330 ohm, 1/4W, 5%	20001-002
R65	Resistor, 47K, 1/2W, 5%	20000-018
R66	Resistor, 1 meg., 1/2W, 5%	20000-002
R67	Resistor, 680 ohm, 1/2W, 5%	20000-019
R68	Resistor, 270K, 1/2W, 5%	20000-006
R69	Resistor, 270K, 1/2W, 5%	20000-006
R70	Resistor, 20K, 1/4W, .5%	20002-512
R71	Resistor, 1K, 1/4W, 5%	20001-001
R72	Resistor, 20K, 1/4W, .5%	20002-512
R73	Potentiometer, 5K	20009-003
R75	Resistor, 270K, 1/2W, 5%	20000-006
R76	Resistor, 680 ohm, 1/2W, 5%	20000-019
R77	Resistor, 6.8K, 1W, 5%	20001-501
R78	Resistor, 270K, 1/2W, 5%	20000-006
R79	Resistor, 270 ohm, 1/2W, 5%	20000-007
R80	Resistor, 100K, 1/2W, 5%	20000-004
R81	Resistor, 6.8K, 1W, 5%	20001-501
R82	Resistor, 270 ohm, 1/2W, 5%	20000-007
R83	Resistor, 56K, 1/2W, 5%	20000-003
R84	Resistor, 1K, 1/4W, 5%	20001-001
R85	Resistor, 1 meg., 1/2W, 5%	20000-002
R86	Resistor, 10K, 1/2W, 5%	20000-020
R87	Potentiometer, 10K, 2W, 10%	20009-002
R88	Resistor, 470 ohm, 1/2W, 5%	20000-021
R89	Resistor, 12K, 1W, 5%	20001-500
R90	Potentiometer, 100K, 2W, 10%	20009-004
R91	Resistor, 56K, 1/2W, 5%	20000-003
R92	Resistor, 1K, 1/4W, 5%	20001-001
R191	Resistor, 100K, 1/2W, 5%	20000-004
R192	Resistor, 100K, 1/2W, 5%	20000-004
R193	Resistor, 500 ohm, 1/4W, .5%	20002-505
R194	Resistor, 500 ohm, 1/4W, .5%	20002-505
R195	Resistor, 500 ohm, 1/4W, .5%	20002-505
R196	Resistor, 500 ohm, 1/4W, .5%	20002-505
R197	Resistor, 33K, 1/2W, 5%	20000-001
R198	Resistor, 33K, 1/2W, 5%	20000-001
R199	Potentiometer, 50K, 2W, 10%	20009-010
R200	Resistor, 270K, 1/2W, 5%	20000-006

Table 5-1. Replaceable Parts (Continued)

EFERENCE SIGNATION	DESCRIPTION	PART NUMBER
R201	Resistor, 270 ohm, 1/2W, 5%	20000-007
R202	Resistor, 18K, 1/2W, 5%	20000-024
R203	Resistor, 56K, 1/2W, 5%	20001-003
R204	Resistor, 1K, 1/4W, 5%	20001-001
R205	Resistor, 1K, 1/4W, 5%	20001-001
R206	Resistor, 270K, 1/2W, 5%	20000-006
R207	Resistor, 56K, 1/2W, 5%	20000-003
R208	Resistor, 1K, 1/4W, 5%	20001-001
R209	Resistor, 1.5K, 1/2W, 5%	20000-025
R229	Resistor, 100K, 1/2W, 5%	20000-004
R230	Resistor, 1 Meg., 1/2W, 5%	20000-002
R231	Resistor, 82K, 1/2W, 5%	20000-028
R232	Resistor, Factory Adjustment	-----
R233	Resistor, 1 Meg., 1/2W, 5%	20000-002
R236	Resistor, 7.5K, 1/2W, 5%	20000-030
R237	Resistor, 7.5K, 1/2W, 5%	20000-030
R238	Resistor, 1 Meg., 1/2W, 5%	20000-002
R239	Resistor, 3K, 1/2W, 5%	20000-033
R240	Resistor, 82K, 1/2W, 5%	20000-028
R241	Resistor, 100K, 1/2W, 5%	20000-004
R242	Resistor, 100K, 1/2W, 5%	20000-004
R243	Resistor, 100K, 1/2W, 5%	20000-004
R244	Resistor, 24.37K, 1/4W, .5%	20002-532
C1	Capacitor, 1 Mfd, 1500V	20004-001
C2	Capacitor, 1 Mfd, 200V	20005-005
C3	Capacitor, 300 Mfd, 3V	20004-006
C4	Capacitor, .47 Mfd, 200V	20005-001
C5	Capacitor, 4 Mfd, 200V	20005-006
C6	Capacitor, .47 Mfd, 200V	20005-001
C8	Capacitor, .1 Mfd, 200V	20005-002
C9	Capacitor, 120 Pfd, 500V	20006-001
C10	Capacitor, .1 Mfd, 200V	20005-002
C11	Capacitor, 560 Pfd, 500V	20006-002
C13	Capacitor, 820 Pfd, 500V	20006-003
C14	Capacitor, .1 Mfd, 200V	20005-002
C15	Capacitor, .01 Mfd, 400V	20005-500
C16	Capacitor, 560 Pfd, 500V	20006-002
C17	Capacitor, .1 Mfd, 200V	20005-002
C18	Capacitor, .047 Mfd, 200V	20005-003
C19	Capacitor, .047 Mfd, 200V	20005-003

Table 5-1. Replaceable Parts (Continued)

REFERENCE DESIGNATION	DESCRIPTION	PART NUMBER
C20	Capacitor, 120 Pfd, 500V	20006-001
C21	Capacitor, .01 Mfd, 400V	20005-500
C22	Capacitor, .1 Mfd, 200V	20005-002
C23	Capacitor, .1 Mfd, 200V	20005-002
C24	Capacitor, .1 Mfd, 200V	20005-002
C25	Capacitor, .001 Mfd, 500V	20006-004
C26	Capacitor, 150 Pfd, 500V	20006-005
C28	Capacitor, 0-30 Pfd	20004-004
C29	Capacitor, 120 Pfd, 500V	20006-001
C30	Capacitor, 120 Pfd, 500V	20006-001
C31	Capacitor, 39 Pfd, 500V	20006-009
C32	Capacitor, .1 Mfd, 200V	20005-002
C34	Capacitor, .1 Mfd, 200V	20005-002
C35	Capacitor, .006 Mfd, 600V	20006-500
C36	Capacitor, .012 Mfd, 600V	20006-501
C37	Capacitor, .012 Mfd, 600V	20006-501
C38	Capacitor, .006 Mfd, 600V	20006-500
C39	Capacitor, 1 Mfd, 200V	20005-005
C40	Capacitor, 300 Mfd, 3V	20004-006
C41	Capacitor, 4 Mfd, 200V	20005-006
C42	Capacitor, .1 Mfd, 200V	20005-002
C43	Capacitor, 1 Mfd, 200V	20005-005
C44	Capacitor, .47 Mfd, 200V	20005-001
C54	Capacitor, 4 Mfd, 200V	20005-006
C64	Capacitor, 4 Mfd, 200V	20005-006
C65	Capacitor, 120 Pfd, 500V	20006-001
C66	Capacitor, 3300 Pfd, 600V	20006-502
C67	Capacitor, 750 Pfd, 500V	20006-010
C68	Capacitor, 750 Pfd, 500V	20006-010
C69	Capacitor, 4700 Pfd, 600V	20006-503
C71	Capacitor, 1000 Pfd, 500V	20006-505
C72	Capacitor, .1 Mfd, 200V	20005-002
C73	Capacitor, 1000 Pfd, 500V	20006-505
C78	Capacitor, 120 Pfd, 500V	20006-001
C80	Capacitor, .006 Mfd, 600V	20006-500
C81	Capacitor, 5 Pfd, 500V	20004-005
C82	Capacitor, Var, Air, 24-200 Pfd, 350V	20004-003
C83	Capacitor, .01 Mfd, 400V	20005-500
C84	Capacitor, .01 Mfd, 400V	20005-500

Table 5-1. Replaceable Parts (Continued)

REFERENCE DESIGNATION	DESCRIPTION	PART NUMBER
C85	Capacitor, Var, Air, 24-200 Pfd, 350V	20004-003
C86	Capacitor, Var, Air, 24-200 Pfd, 350V	20004-003
C87	Capacitor, .01 Mfd, 400V	20005-500
C88	Capacitor, 40/40 Mfd, 200/250 WVDC	20004-010
C89	Capacitor, 40/40 Mfd, 200/250 WVDC	20004-010
C90	Capacitor, Var, Air, 24-200 Pfd, 350V	20004-300
C91	Capacitor, 560 Pfd, 500V	20006-002
CR1	Diode, 1N1735	20008-014
CR4	Diode 1N473	20008-012
CR9A,B	Diode, CD 6112	20008-003
CR10A,B	Diode, CD 6112	20008-003
CR2A,B	Diode, CD 6112	20008-003
CR3A,B,C,D	Diode, CD 6112	20008-003
CR8	Diode, 1N773	20008-001
CR5	Diode, 1N773	20008-001
CR6	Diode, 1N773	20008-001
CR7A	Crystal, JKH 17 T	20011-002
CR7B	Oven, JK 010	20011-003
M1	Meter, Mod. 561	10003
M2	Meter, Mod. 361	10002
T1	Transformer, F-13X	20011-018
T2	Transformer, 10K, 1K	20011-015
T3	Transformer, 10K, 1K	20011-015
T4	Transformer, 10K, 1K	20011-015
T5	Transformer, 10K, 1K	20011-015
T6	Transformer, 10K, 1K	20011-015
T8	Transformer, F51X	
L1	Coil, 3MH	20008-500
L2	Coil, 3MH	20008-500
L3	Coil, 3MH	20008-500
L4	Coil, 3MH	20008-500
L5	Coil, 3MH	20008-500
L6	Coil, 3MH	20008-500
L7	Coil, .47MH	20008-501

Table 5-1. Replaceable Parts (Continued)

EFERENCE ESIGNATION	DESCRIPTION	PART NUMBER
V1	Nuvistor, 7895	20011-004
V2	Nuvistor, 7895	20011-004
V3	Nuvistor, 7895	20011-004
V4	Nuvistor, 7895	20011-004
V5	Nuvistor, 7895	20011-004
V6	Nuvistor, 7895	20011-004
V7	Nuvistor, 7895	20011-004
V8	Nuvistor, 7895	20011-004
V9	Nuvistor, 7895	20011-004
V10	Nuvistor, 7895	20011-004
V11	Nuvistor, 7586	20011-012
V12	Nuvistor, 7586	20011-012
V13	Nuvistor, 7895	20011-004
V14	Nuvistor, 7586	20011-012
V15	Nuvistor, 7895	20011-004
V16	Nuvistor, 7586	20011-012
V17	Nuvistor, 7895	20011-004
V18	Nuvistor, 7895	20011-004
V19	Nuvistor, 7895	20011-004
V40	Nuvistor, 7895	20011-004
V41	Nuvistor, 7895	20011-004
V42	Nuvistor, 7895	20011-004
S1	Switch, 2P. 6 Pos.	20010-003
S2	Switch, 2P. 12 Pos.	20010-004
S3	Switch, 4P. 6 Pos.	20010-001
S4	Switch, Power	20010-002
F1	Fuse, 2 Amp, 3 AG, Slo-Blo	20011-014
A4	(Upper) Circuit Board	SDC-10025
R1	Resistor, 1K, 1/4W, 5%	20001-001
R2	Resistor, 220K, 1/2W, 5%	20000-023
R3	Resistor, 20K, 1/4W, .5%	20002-512
R4	Resistor, 1K, 1/4W, .5%	20001-001
R5	Resistor, 20K, 1/4W, .5%	20002-512
R6	Potentiometer, 20K	20009-005

Table 5-1. Replaceable Parts (Continued)

REFERENCE DESIGNATION	DESCRIPTION	PART NUMBER
R7	Resistor, 750K, 1/4W, 1%	20002-533
R8	Resistor, 1K, 1/4W, 5%	20001-001
R9	Resistor, 20K, 1/4W, .5%	20002-512
R10	Resistor, 20K, 1/4W, .5%	20002-512
R11	Potentiometer, 10K, Factory Adjust.	20009-006
R12	Resistor, 126K, 1/4W, 1%	20002-534
R13	Resistor, 1K, 1/4W, 5%	20001-001
R14	Resistor, 20K, 1/4W, .5%	20002-512
R15	Resistor, 20K, 1/4W, .5%	20002-512
R16	Potentiometer, 10K, Factory Adjust.	20009-006
R17	Resistor, 238K, 1/4W, 1%	20002-535
R18	Resistor, 1K, 1/4W, 5%	20001-001
R19	Resistor, 20K, 1/4W, .5%	20002-512
R20	Resistor, 20K, 1/4W, .5%	20002-512
R21	Potentiometer, 20K, Factory Adjust.	20009-005
R22	Resistor, 446K, 1/4W, 1%	20002-536
R23	Resistor, 1K, 1/4W, 5%	20001-001
R24	Resistor, 20K, 1/4W, .5%	20002-512
R25	Resistor, 20K, 1/4W, .5%	20002-512
R26	Potentiometer, 5K, Factory Adjust.	20009-007
R27	Resistor, 102K, 1/4W, 1%	20002-537
R28	Resistor, 1K, 1/4W, 5%	20001-001
R29	Resistor, 20K, 1/4W, .5%	20002-512
R30	Resistor, 20K, 1/4W, .5%	20002-512
R31	Potentiometer, 10K, Factory Adjust.	20009-006
R32	Resistor, 235K, 1/4W, 1%	20002-538
R33	Resistor, 1K, 1/4W, 5%	20001-001
R34	Resistor, 20K, 1/4 W, .5%	20002-512
R35	Resistor, 20K, 1/4W, .5%	20002-512
R36	Potentiometer, 5K, Factory Adjust.	20009-007
R37	Resistor, 135K, 1/4W, 1%	20002-558
R38	Resistor, 1K, 1/4W, 5%	20001-001
R39	Resistor, 20K, 1/4W, .5%	20002-512
R40	Resistor, 20K, 1/4W, .5%	20002-512
R41	Potentiometer, 5K, Factory Adjust.	20009-007
R42	Resistor, 118K, 1/4W, 1%	20002-540
R43	Resistor, 1K, 1/4W, 5%	20001-001
R44	Resistor, 20K, 1/4W, .5%	20002-512
R45	Resistor, 20K, 1/4W, .5%	20002-512

Table 5-1. Replaceable Parts (Continued)

REFERENCE DESIGNATION	DESCRIPTION	PART NUMBER
R46	Potentiometer, 5K, Factory Adjust.	20009-007
R47	Resistor, 56.2K, 1/4W, 1%	20002-541
R48	Resistor, 1K, 1/4W, 5%	20001-001
R49	Resistor, 18K, 1/2W, 5%	20000-024
A5	(Lower) Circuit Board	SDC-10026
R1	Resistor, 1K, 1/4W, 5%	20001-001
R2	Resistor, 220K, 1/2W, 5%	20000-023
R3	Resistor, 20K, 1/4W, .5%	20002-512
R4	Resistor, 1K, 1/4W, .5%	20001-001
R5	Resistor, 20K, 1/4W, .5%	20002-512
R6	Potentiometer, 20K, Factory Adjust.	20009-005
R7	Resistor, 261K, 1/4W, 1%	20002-559
R8	Resistor, 1K, 1/4W, 5%	20001-001
R9	Resistor, 20K, 1/4W, .5%	20002-512
R10	Resistor, 20K, 1/4W, .5%	20002-512
R11	Potentiometer, 5K, Factory Adjust.	20009-007
R12	Resistor, 58.6K, 1/4W, 1%	20002-549
R13	Resistor, 1K, 1/4W, 5%	20001-001
R14	Resistor, 20K, 1/4W, .5%	20002-512
R15	Resistor, 20K, 1/4W, .5%	20002-512
R16	Potentiometer, 5K, Factory Adjust.	20009-007
R17	Resistor, 114K, 1/4W, 1%	20002-548
R18	Resistor, 1K, 1/4W, 5%	20001-001
R19	Resistor, 20K, 1/4W, .5%	20002-512
R20	Resistor, 20K, 1/4W, .5%	20002-512
R21	Potentiometer, 20K, Factory Adjust.	20009-005
R22	Resistor, 206K, 1/4W, 1%	20002-547
R23	Resistor, 1K, 1/4W, 5%	20001-001
R24	Resistor, 20K, 1/4W, .5%	20002-512
R25	Resistor, 20K, 1/4W, .5%	20002-512
R26	Potentiometer, 5K, Factory Adjust.	20009-007
R27	Resistor, 47.6K, 1.4W, 1%	20002-546
R28	Resistor, 1K, 1/4W, 5%	20001-001
R29	Resistor, 20K, 1/4W, .5%	20002-512
R30	Resistor, 20K, 1/4W, .5%	20002-512
R31	Potentiometer, 5K, Factory Adjust.	20009-007
R32	Resistor, 110K, 1/4W, 1%	20002-545
R33	Resistor, 1K, 1/4W, 5%	20001-001

Table 5-1. Replaceable Parts (Continued)

REFERENCE DESIGNATION	DESCRIPTION	PART NUMBER
R34	Resistor, 20K, 1/4W, .5%	20002-512
R35	Resistor, 20K, 1/4W, .5%	20002-512
R36	Potentiometer, 5K, Factory Adjust.	20009-007
R37	Resistor, 63K, 1/4W, 1%	20002-544
R38	Resistor, 1K, 1/4W, 5%	20001-001
R39	Resistor, 20K, 1/4W, .5%	20002-512
R40	Resistor, 20K, 1/4W, .5%	20002-512
R41	Potentiometer, 5K, Factory Adjust.	
R42	Resistor, 54.7K, 1/4W, 1%	20002-543
R43	Resistor, 1K, 1/4W, 5%	20001-001
R44	Resistor, 20K, 1/4W, .5%	20002-512
R45	Resistor, 20K, 1/4W, .5%	20002-512
R46	Potentiometer, 2K, Factory Adjust.	20009-009
R47	Resistor, 17.9K, 1/4W, 1%	20002-542
R48	Resistor, 1K, 1/4W, 5%	20001-001
R49	Resistor, 18K, 1/2W, 5%	20000-024
A4	(Upper) Circuit Board	SDC-10025
C1	Capacitor, .68 Mfd, 200V, 1%	20005-007
C2	Capacitor, .68 Mfd, 200V, 1%	20005-007
C3	Capacitor, .082 Mfd, 200V, 1%	20005-008
C4	Capacitor, .01 Mfd, 200V, 1%	20005-009
C5	Capacitor, .01 Mfd, 200V, 1%	20005-009
C6	Capacitor, .001 Mfd, 200V, 1%	20006-004
C7	Capacitor, 390 Pfd, 200V, 1%	20006-007
C8	Capacitor, 100 Pfd, 200V, 1%	20006-007
C9	Capacitor, 50 Pfd, 200V, 1%	20006-008
V1 thru V10	Nuvistor 7895	20011-004
A5	(Lower) Circuit Board	SDC-10026
C1	Capacitor, .68 Mfd, 200V, 1%	20005-007
C2	Capacitor, .68 Mfd, 200V, 1%	20005-007
C3	Capacitor, .082 Mfd, 200V, 1%	20005-008
C4	Capacitor, .01 Mfd, 200V, 1%	20005-009

Table 5-1. Replaceable Parts (Continued)

EFERENCE ESIGNATION	DESCRIPTION	PART NUMBER
C5	Capacitor, .01 Mfd, 200V, 1%	20005-009
C6	Capacitor, .001 Mfd, 200V, 1%	20006-004
C7	Capacitor, 390 Pfd, 200V, 1%	20006-007
C8	Capacitor, 100 Pfd, 200V, 1%	20006-007
C9	Capacitor, 50 Pfd, 200V, 1%	20006-008
V1 thru V10	Nuvistor 7895	20011-004

APPLICATIONS

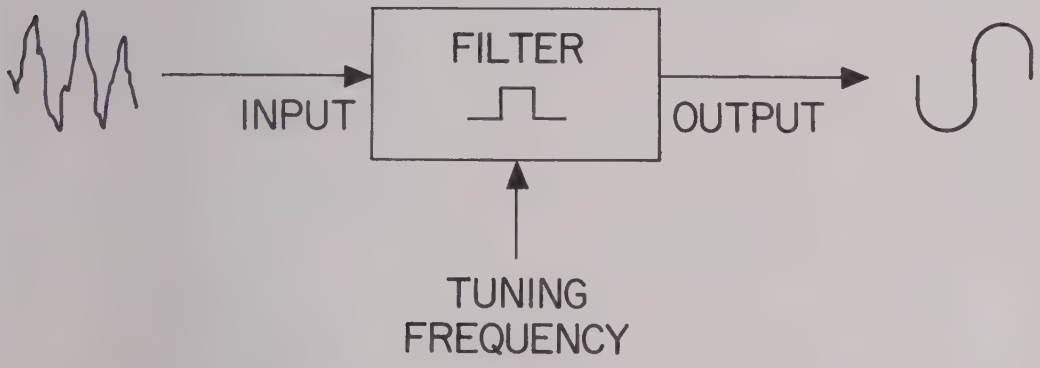
DYNAMIC ANALYZER

SPECTRAL DYNAMICS CORPORATION OF SAN DIEGO

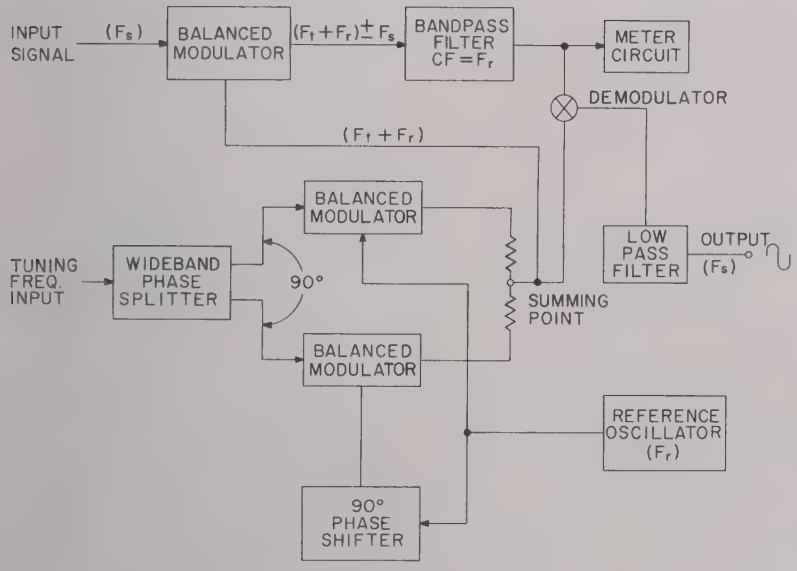
1162 Morena Blvd., San Diego 10, California BRowning 6-2331

IDEALIZED CONCEPT OF THE DYNAMIC ANALYZER

The Spectral Dynamics Corporation DYNAMIC ANALYZER is a newly developed multipurpose instrument offering exceptional application versatility in the fields of vibration, acoustical and electrical analysis and measurement. The Analyzer is essentially an inherently frequency-tuned bandpass filter. The center frequency of the instrument is continuously and precisely tuned to track the frequency from an external source. It is a completely frequency-tuned system and does not depend on an internal servo or utilize frequency to DC conversion for its unique operation.

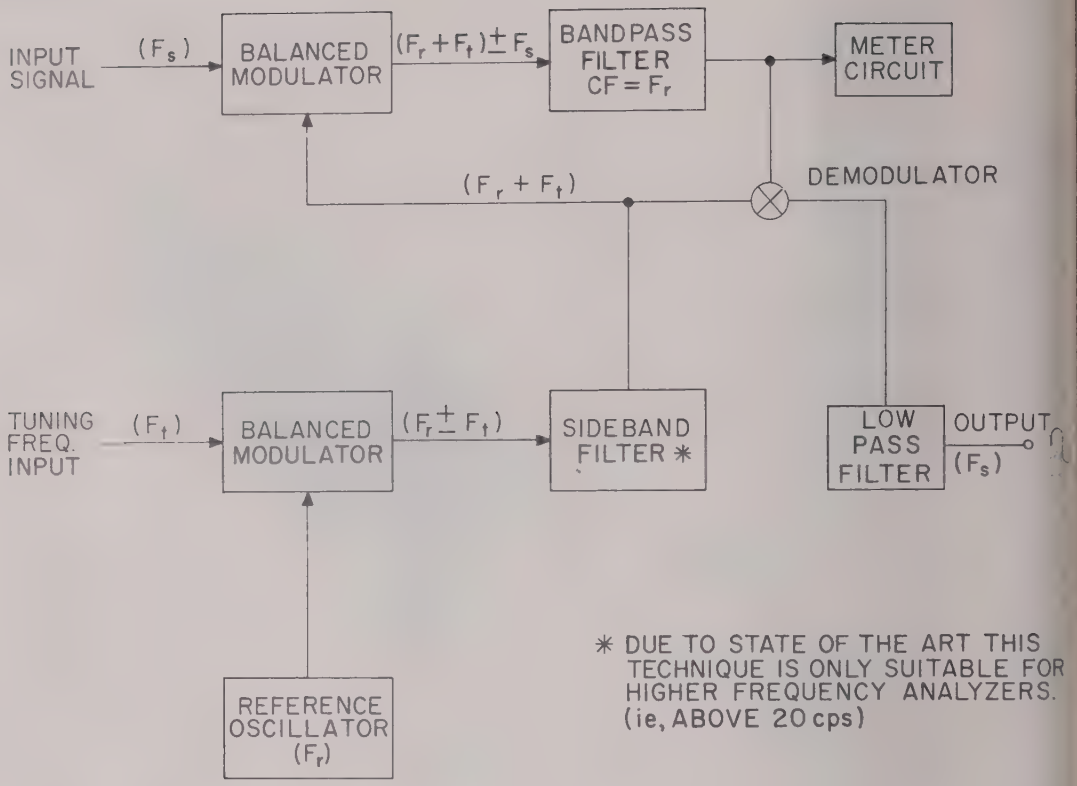


TECHNIQUES BY WHICH THIS IS ACCOMPLISHED:



Method 1 - This technique is useful to below 1 cps.

Patent No. 3,018,439



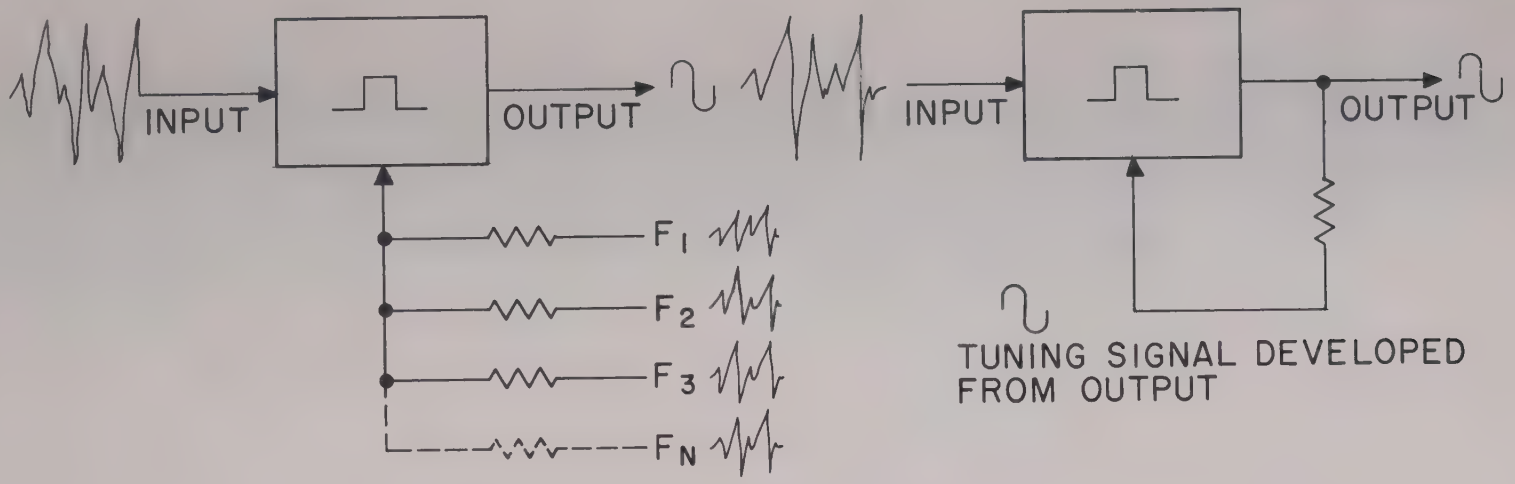
Method 2

APPLICATIONS

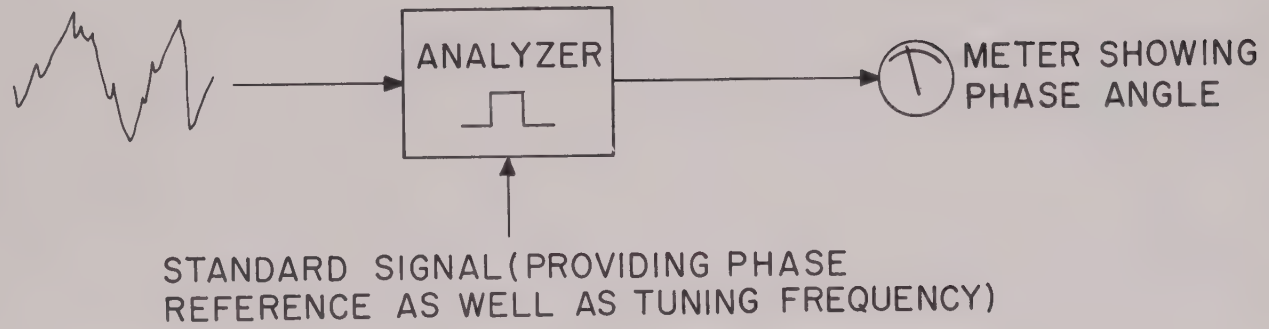
The following applications, employing the frequency-tuned bandpass filter, are presently being studied. They are shown in block diagram form to illustrate the wide variety of applications that are possible.

Primary concentration to date has been in the field of jet engine analysis. Applications in the fields of Television, Communication, Radar, Sonar, Guidance and Control Systems, Data Transmission, Target Tracking, Aircraft Approach Control, and any of the fields other than purely Vibration Analysis, are presently being studied. Undoubtedly there would be many applications in the fields mentioned above, and should the reader have a particular application in mind, he should feel free to call on our engineering staff to discuss and to help work out the application in detail.

FREQUENCIES AT ONCE

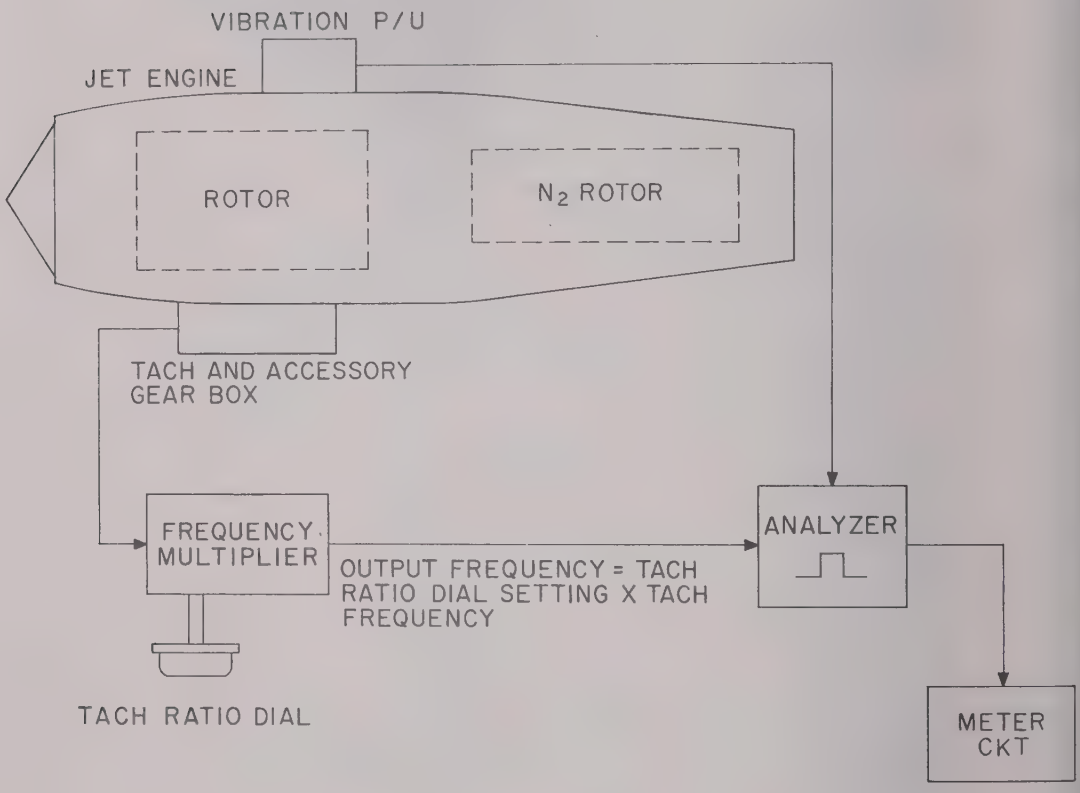


3. PHASE MEASUREMENTS



I. VIBRATION ANALYSIS of rotating machinery, i.e., jet engines, motors, turbines, gyros, etc.

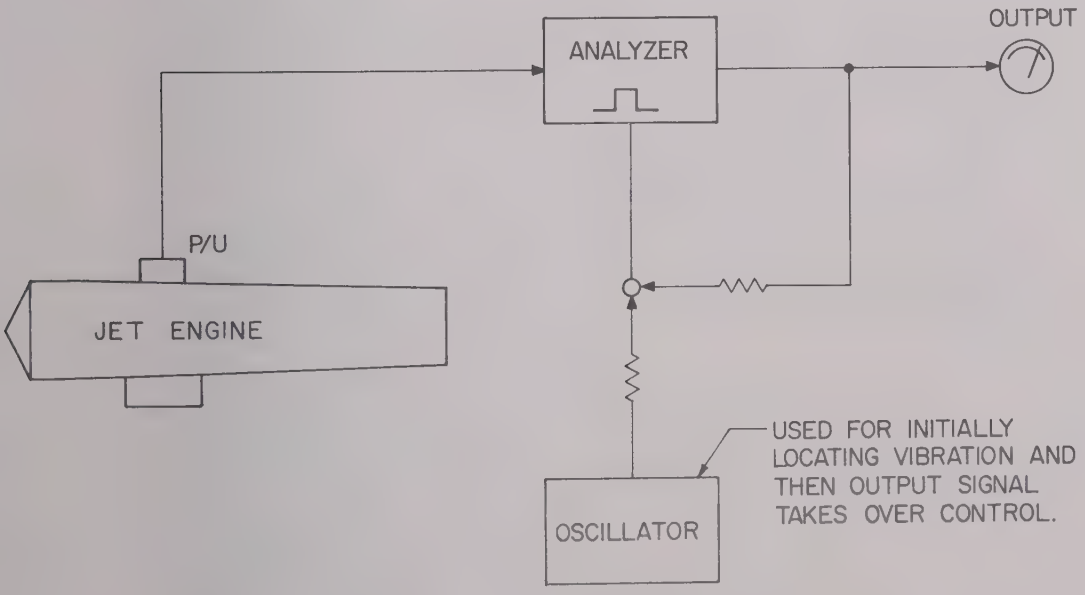
Purpose: To determine sources and magnitudes of the vibration from a machine to facilitate repair, engineering data, and/or preventive maintenance programs. The equipment with modification would be quite suitable for airborne use, and can be programmed from external sources for automatic checkout systems.



Assume the ratio of the tachometer frequency to the N_1 rotor is 2 or $\frac{\text{Rotor}}{\text{Tach}} = 2$

By multiplying the tach frequency continuously by two, the output from the frequency multiplier will be the rotor's frequency which tunes the filter to pass only the vibration amplitudes and frequency of the rotor. As the engine accelerates, the output of the frequency multiplier is still the rotor frequency and continuously tunes the filter to pass only vibration amplitudes at the rotor frequency.

Note: The tachometer frequency is a function of engine R.P.M. and since the tachometer is geared to the prime rotating shafts, the R.P.M. of the other shafts are related to the tachometer frequency by a constant, or a particular shaft frequency F_s = KX tach frequency. The frequency multiplier is for the purpose of generating tuning signals for the frequency tuned bandpass filter. The output from an engine mounted vibration pickup will contain fundamental frequencies and amplitudes due to the vibrations of the various rotating parts. The analyzer is used to separate and measure these amplitudes and frequencies; and by relating a particular vibration level to a given "Tach Ratio", the vibration level of a particular shaft may be measured and tracked over its operating speed range.



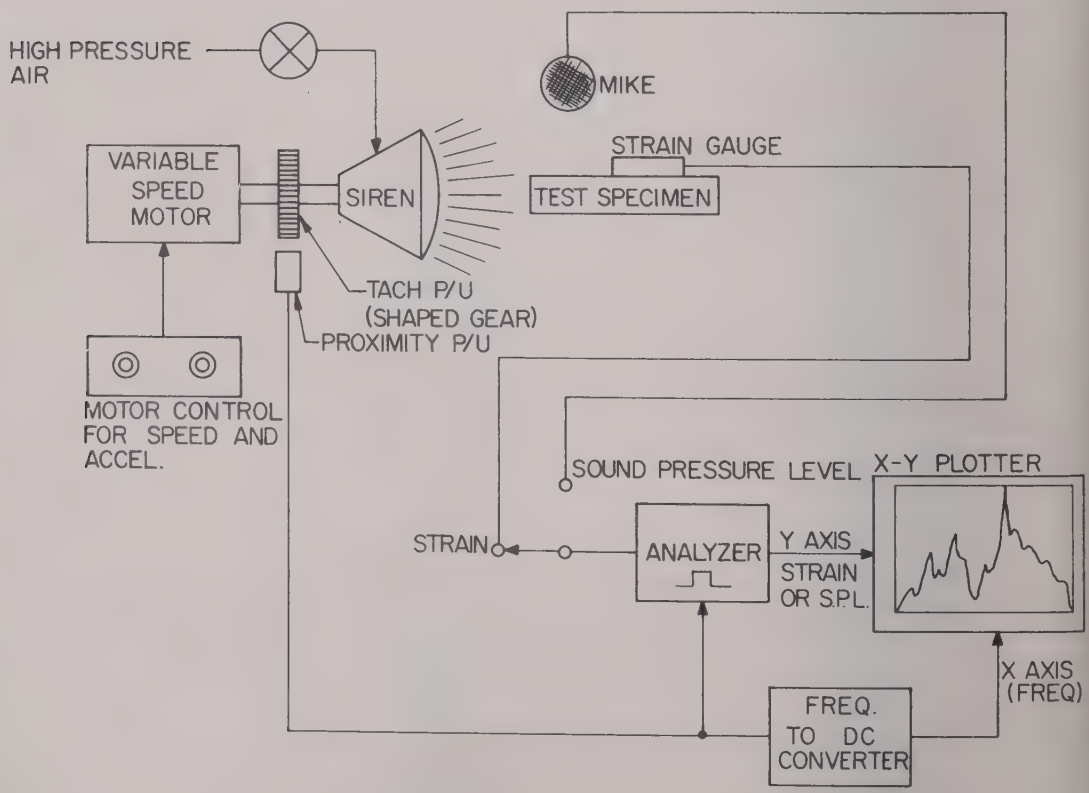
Another approach to tracking selected components of an engine would by by the use of the self-tracking characteristics of the instrument. This is a relatively new concept we have developed and has opened up many new methods of approach. When an output signal exists, the instrument "locks on" the frequency and automatically tracks.

II. SONIC TESTING

Sonic fatigue testing is a new and important field of testing. Its purpose is to determine the fatigue life of various materials and constructions in the presence of high intensity sound sources.

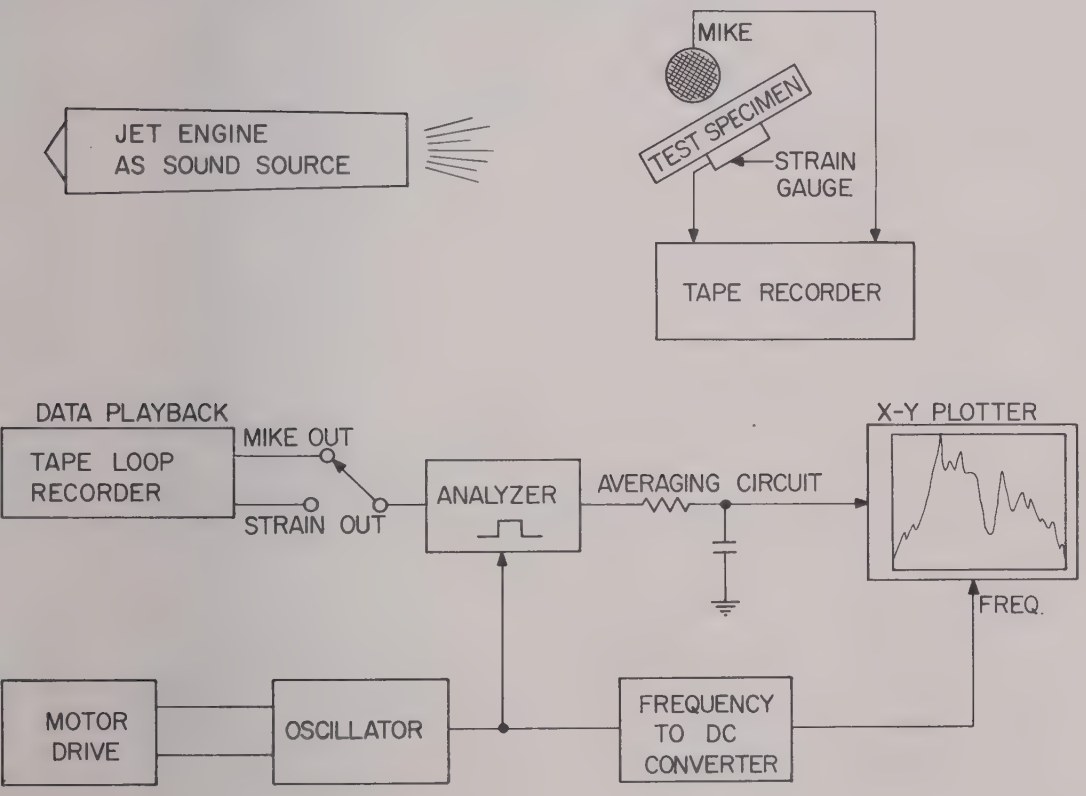
Two types of sound environments are used, i.e., Random and Sinussoidal.

1. Typical setup for sine wave testing:



PURPOSE OF ANALYZER: Due to large amounts of harmonic content in a siren, the analyzer is used to measure the fundamental driving sound pressure level and the fundamental sinusoidal response. If this were not used, errors in measurement would result in that the measuring instruments are calibrated in terms of a sine wave and sinusoidal signals should be used to evaluate response characteristics. The filter also eliminates multiple frequencies, or spurious responses from showing up on frequency response plots.

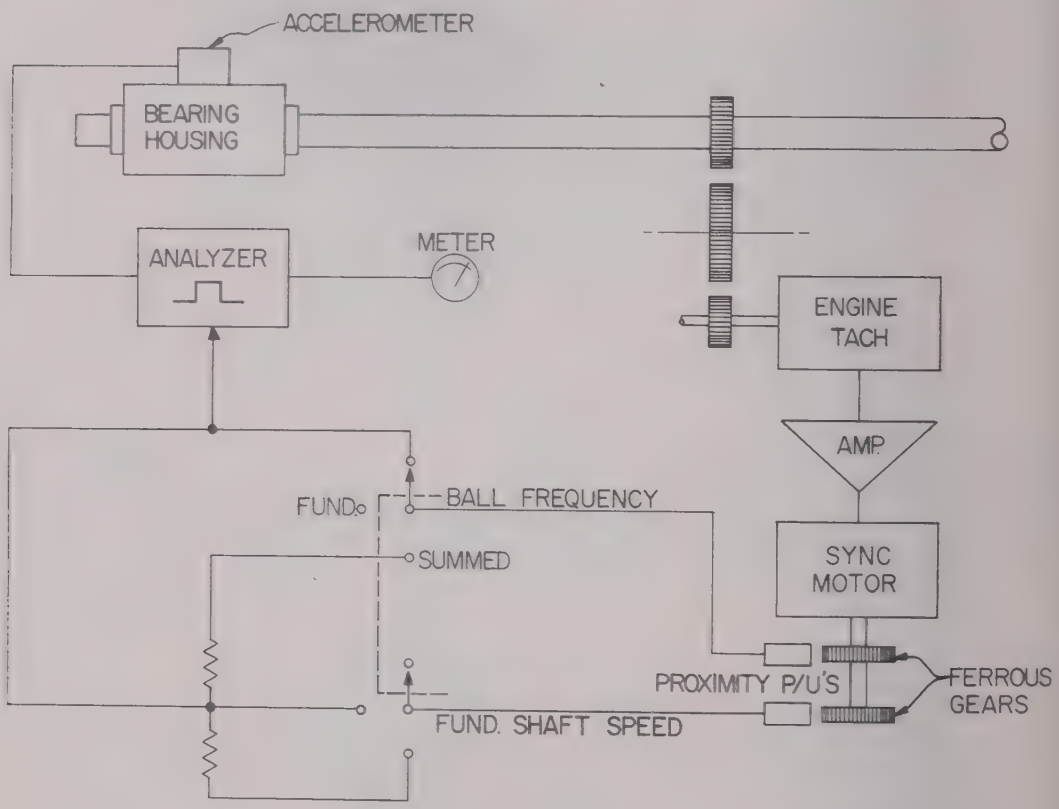
2. Setup for Random testing:



In this application the data is played back from a tape loop recorder. By slowly sweeping the frequency of an oscillator over the desired frequency, plots of average sound pressure, strain, etc., may be obtained.

III. BEARING ANALYSIS

Information gathered during our sales demonstrations indicate that the airlines, engine manufacturers and Air Force are interested in a technique of detecting defective bearings before actual failure occurs. The present technique used by the customer is the measurement of bearing temperatures. This has been found to be very unreliable due to the cooling oil used. The Frequency Tuned Band-Pass Filter provides a natural method for monitoring and detecting these occurrences.



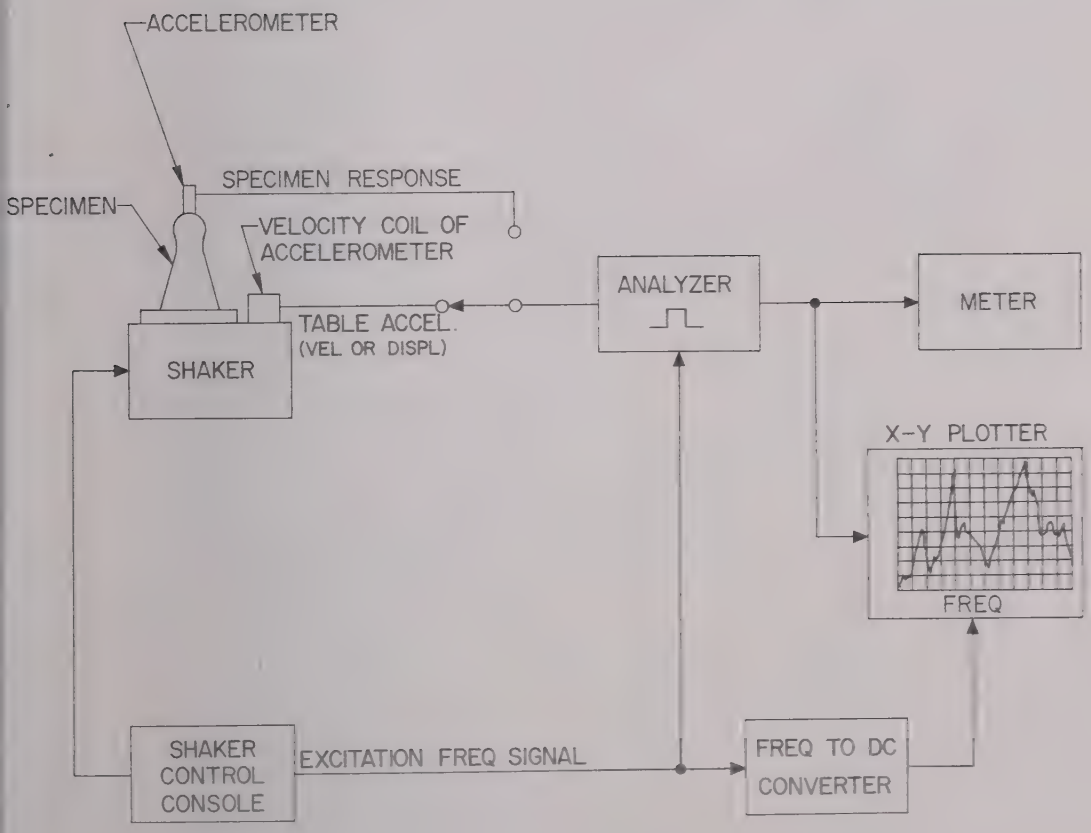
By tuning the analyzer to the ball and fundamental frequencies, the analyzer will indicate the algebraic sum of the two responses and when this exceeds a predetermined level the operator may select the ball or race frequency to determine which one is vibrating excessively.

IV. SHAKER TABLE VIBRATION MONITORING AND CONTROL SYSTEMS

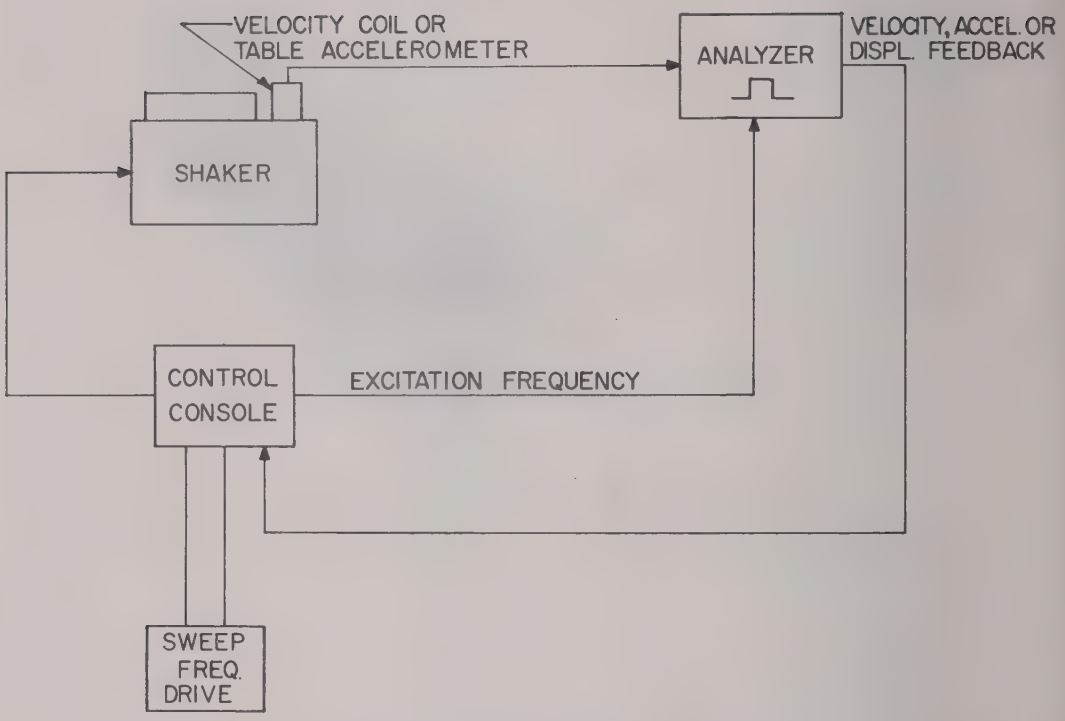
Reference: Attached article by Donald Wrisley entitled: Some Effects of Acceleration Waveform Distortion in Sinusoidal Vibration Testing. Reprinted from Test Engineering Magazine.

PURPOSE OF ANALYZER: To provide measurement of the fundamental acceleration levels and responses of test specimens to remove the effects of waveform distortions from meter and feedback circuits; to apply feedback control voltages for controlling acceleration, velocity or displacement levels of swept shaker systems.

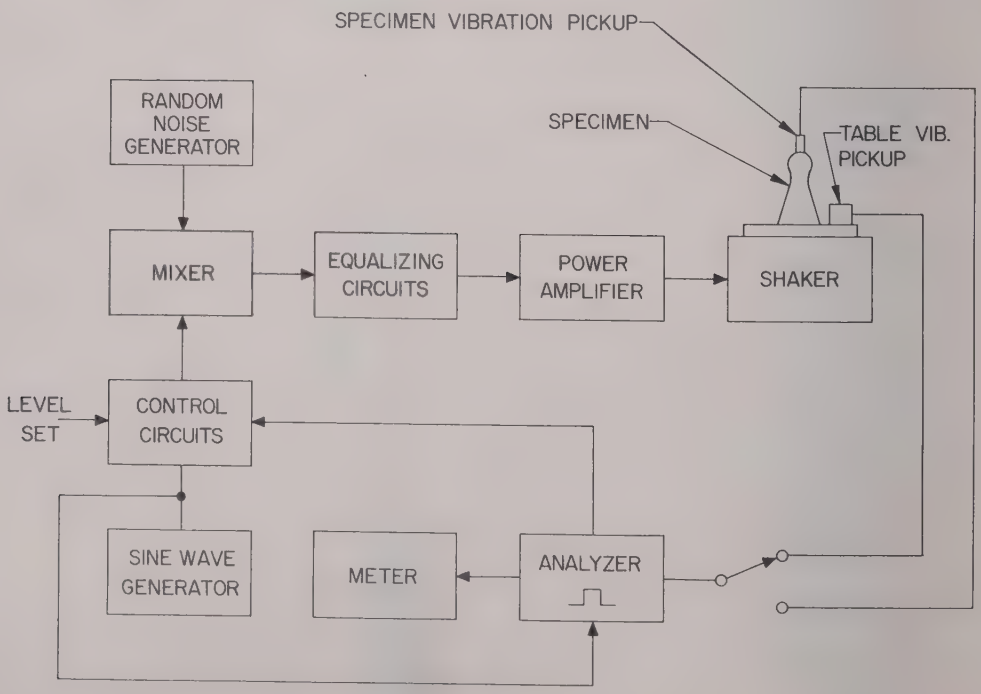
Monitoring and Measurement



Feedback Control



Sine Random Mixed Shaker Systems



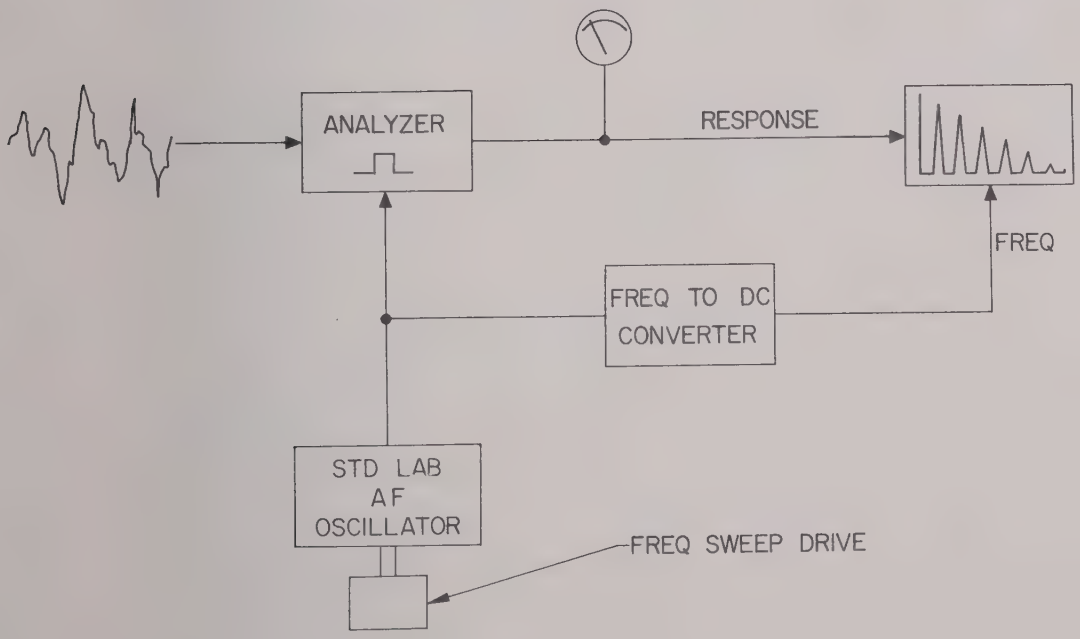
PURPOSE OF ANALYZER: To measure response of shaker and/or specimen to a sine wave component in the presence of random signals and/or for feedback control of sine component applied to the shaker.

V. HARMONIC WAVE ANALYSIS

Purpose: To perform Fourier analysis of periodic wave forms; to measure characteristics of transmission lines, distortion components, etc.

Advantages: Our analyzer has superior stability over conventional types of analyzers, thus gives more reliable and accurate results. Meter display or X-Y plots may be obtained. Also by utilizing the self-tracking feature, the system would "lock" onto the frequency component making the unit much easier to use and tune.

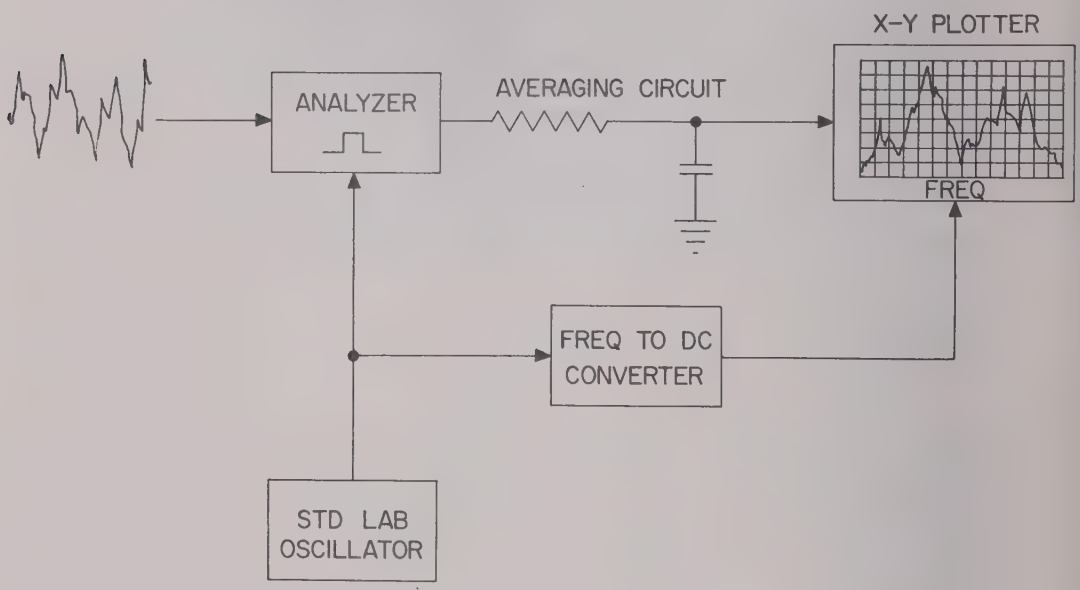
Our analyzer eliminates the need for the critical, expensive high frequency tunable local oscillator used in conventional analyzers, and provides much more operational versatility.



VI. RANDOM WAVE ANALYSIS

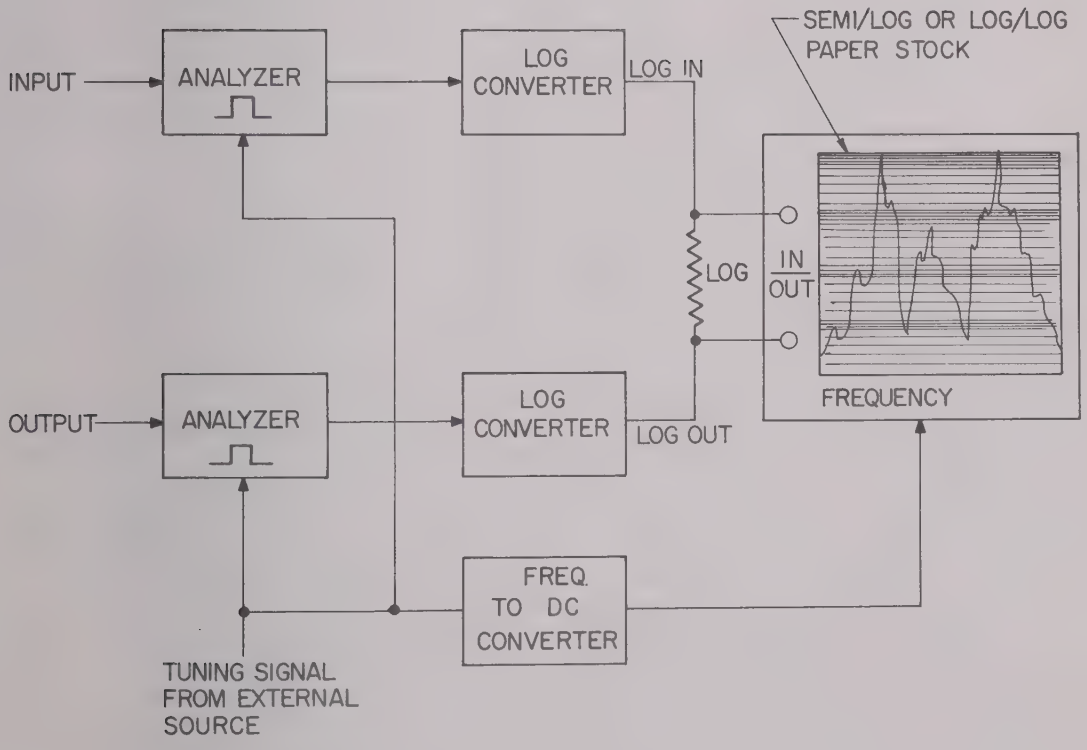
Purpose: To provide data on spectral density or average g/cycle vs. frequency for missiles, gust analysis, Random vibration tests, environmental determination.

Advantages: This instrument provides superior stability and application versatility, plus easily expanded into "comb" filter arrangements.



VII. TRANSMISSIBILITY AND MECHANICAL IMPEDANCE

Purpose: To obtain normalized plots of input/output or fundamental driving/response functions of two signals in a high noise environment. May be used for shake table analysis, mechanical impedance, flutter testing, sonic testing, and any other application where this type of data is being obtained.

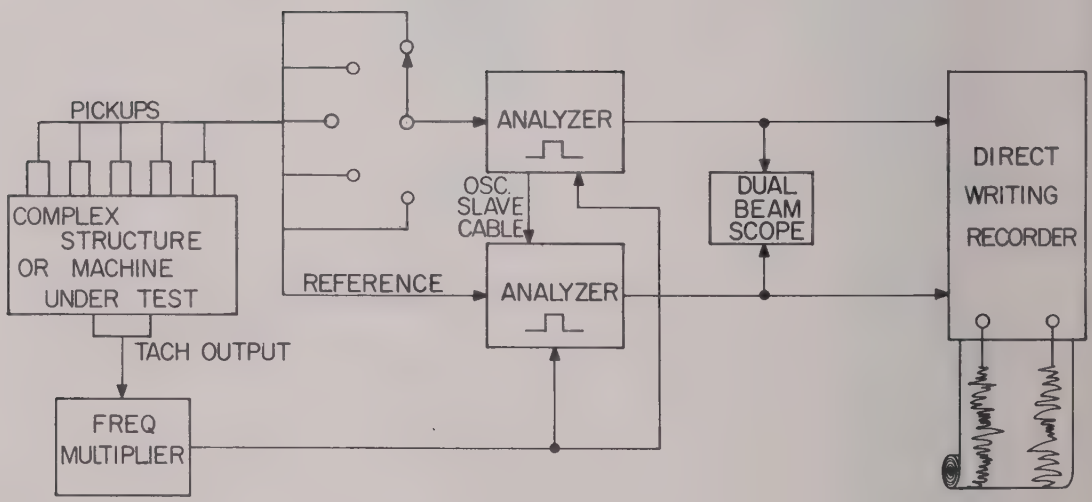


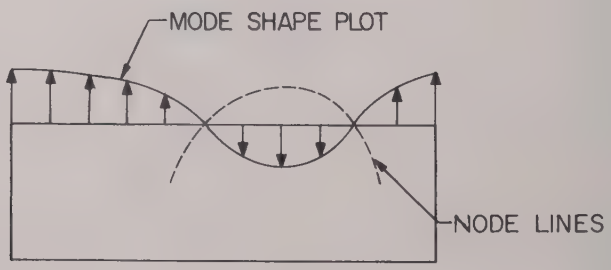
VIII. (Tentative)

MULTI-FILTER INSTALLATIONS for mode shape plotting in noise environments. (Mode shapes are plots of relative amplitudes and phasing.)

For: Jet engines, motors, turbines, aircraft, etc.

Advantages: Our instrument makes obtaining this type of data practical.





IX. FLUTTER TESTING

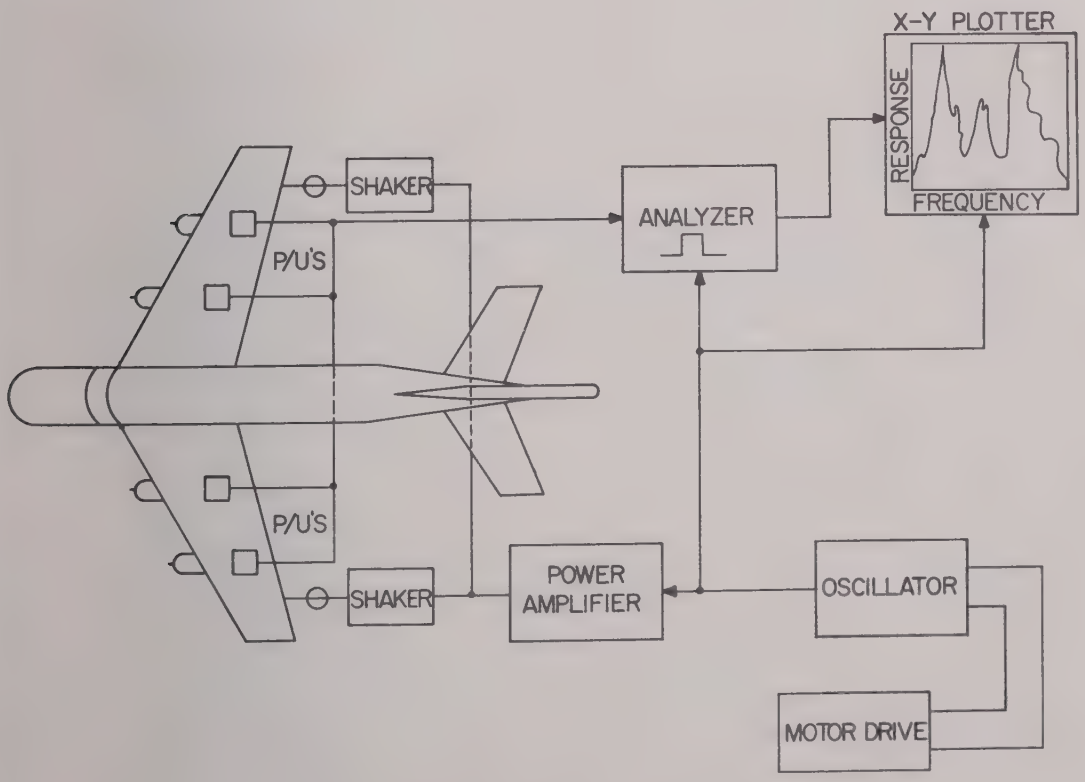
In flutter testing there are usually several types of vibration tests and test programs performed before an experimental aircraft is certified.

These tests usually include ground vibration tests of dynamic similar models, followed by wind tunnel tests to determine the models margin of stability. (This includes control surfaces and major air foils.)

When the first prototype aircraft is completed, a ground vibration test is then performed to compare computed modes with airplane and model modes. Following the aircraft ground vibration tests, flight flutter tests are performed to establish the aircrafts margin of stability. Each phase of the test program presents its own particular problems and many different test techniques are used. Certain missile tests are conducted along similar lines.

How the Analyzer is applied to each phase is described below:

A. Model Ground Vibration Tests.



The analyzer can be used when making automatic plots of frequency versus response to eliminate effects noisy test locations and multiple frequencies from showing up on the frequency versus response plots.

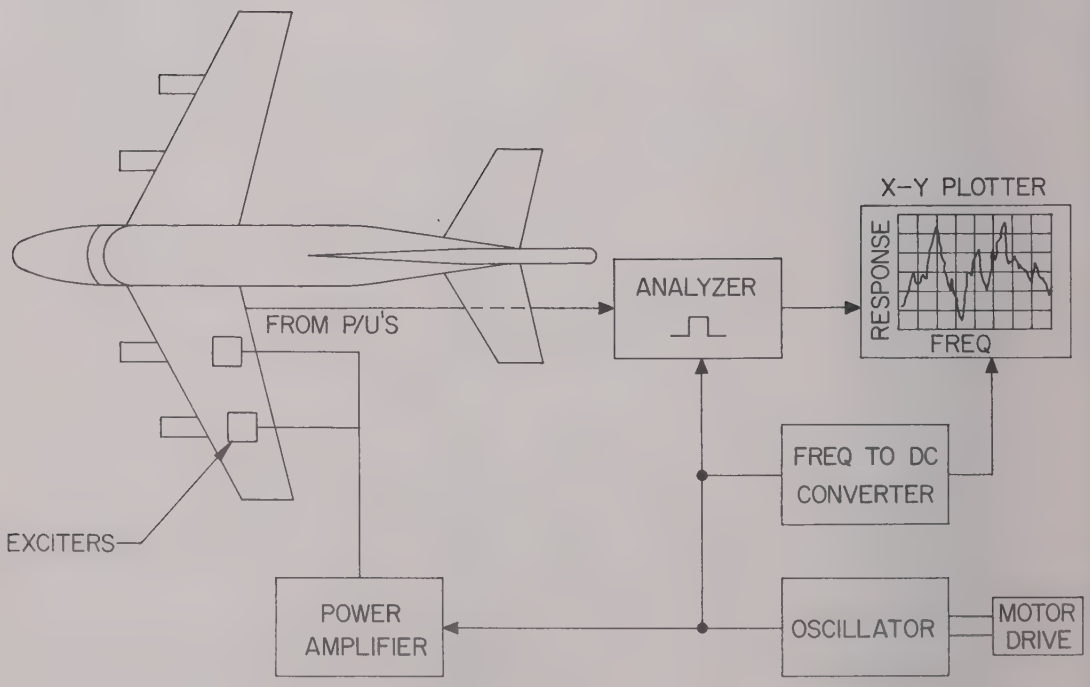
The purpose of the plots are to define the frequency location of the models natural modes of vibration.

B. Model Wind Tunnel Tests

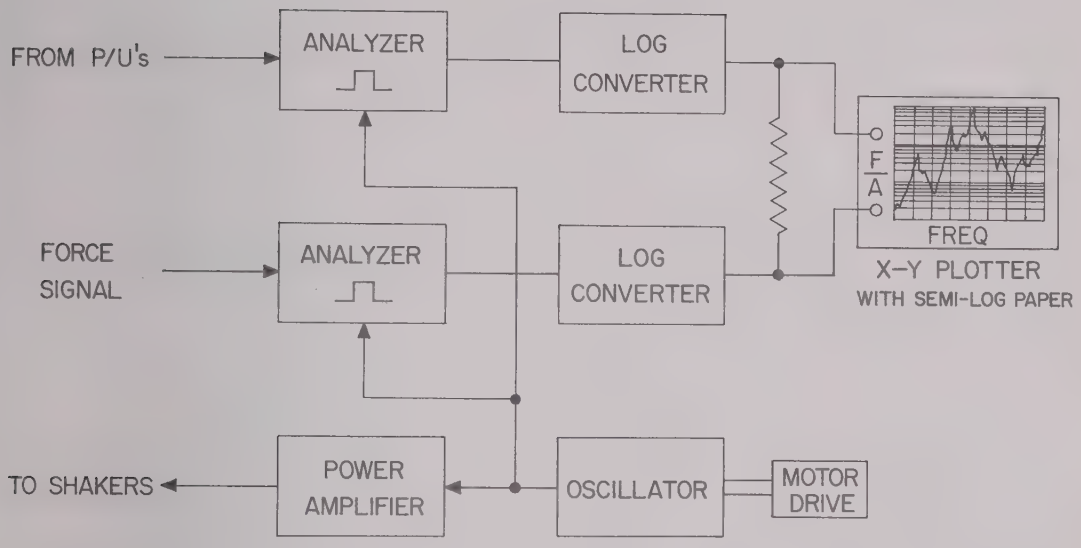
There are various techniques for conducting wind tunnel tests. I will describe three (3) types:

1. Models with sinusoidal excitation
2. Models that are excited by a step function (by "jerk" wire)
3. Models subjected to random excitations

1. (a) Sinusoidal Excitation



(b) Sinusoidal excitation measuring input force/amplitude.

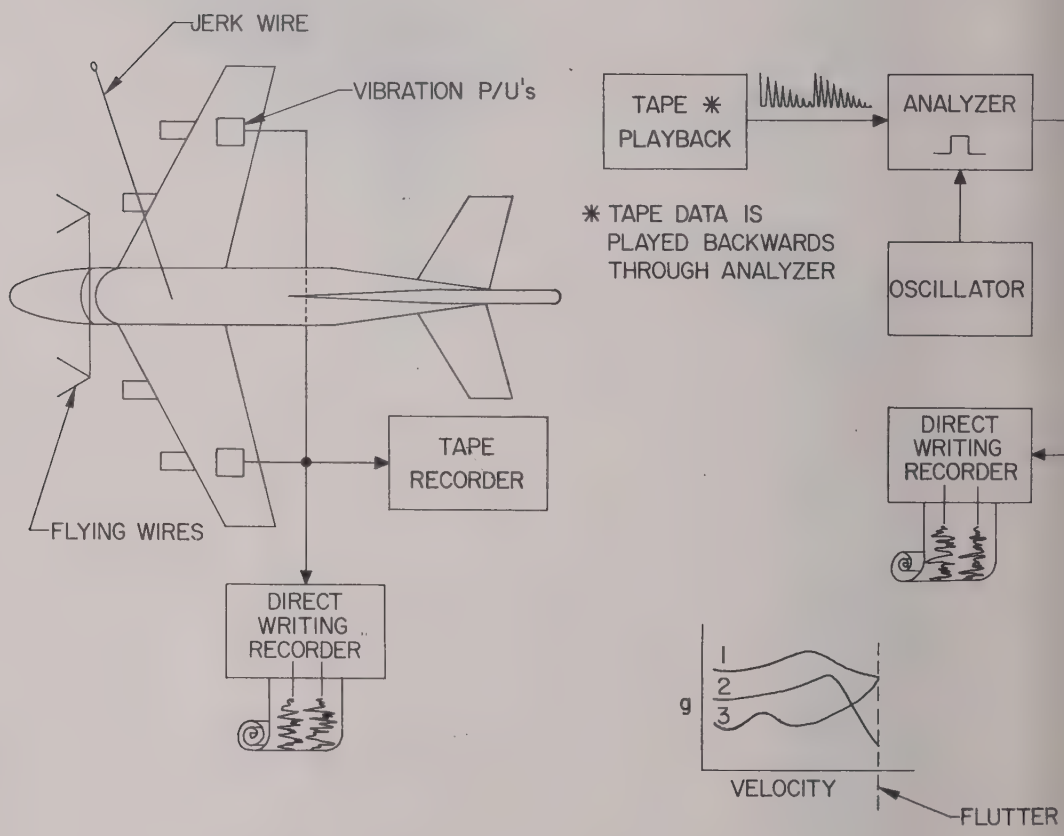


The advantage of the F/A plot is that obtaining one plot at a given test velocity provides all the necessary data at that velocity. By plotting F/A of each mode vs. test velocity flutter can be predicted because as flutter is approached $\frac{F}{A} \rightarrow 0$.

2. Jerk Wire Excitation

With this method it is very often difficult to get good data. Data reduction cannot easily be made on an "on line" basis.

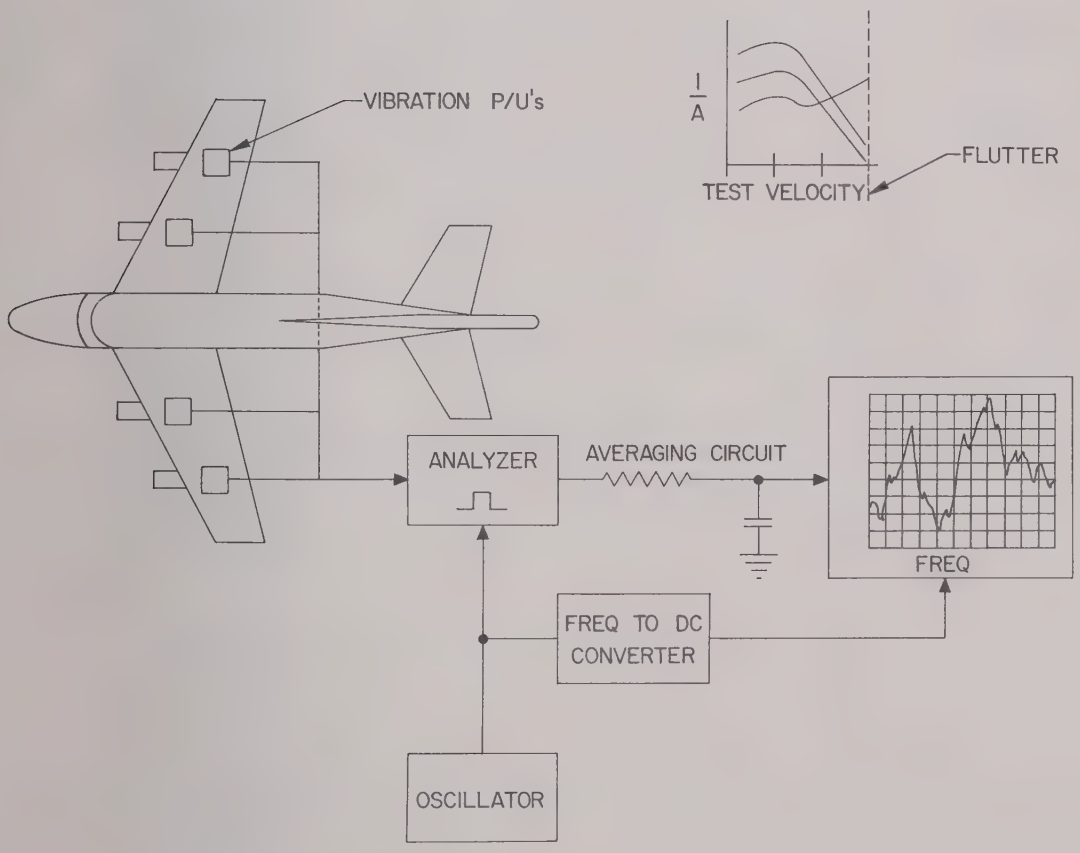
The technique is that of plotting Logarithmic Decrement ("g") versus test velocity for each natural mode. To obtain this data a wire attached to the model is "jerked" and a recording of decays made.



Filter characteristics are quite important in this application. The analyzer separates the frequencies of the various modes that are excited and allows each modes damping to be measured.

3. Random Excitation

Some wind tunnels exhibit rather high turbulence levels that can be used to provide adequate excitation for some model tests. It is assumed that the power spectral density of the turbulence is some function of velocity and is repeatable between runs. The analyzer is used to analyze the models average random response versus frequency at various tunnel speeds to predict flutter.

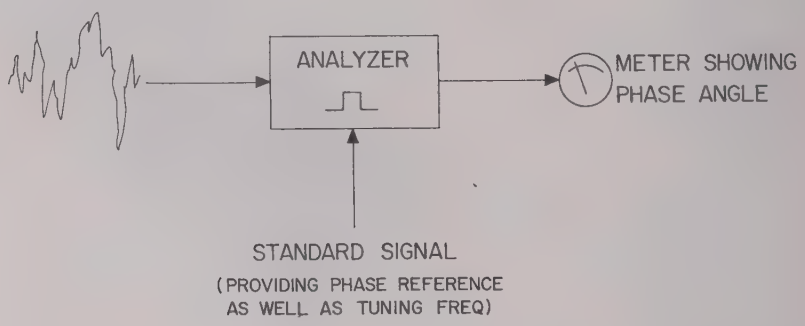


TYPICAL FOR RANDOM EXCITATION

Fullscale aircraft are usually tested with some form of sinusoidal excitation and the data telemetered or reduced on board depending upon available space in the aircraft. The methods outlined for model tests using sinusoidal exciters or the "jerk wire" method (using control system pulsing) are also used.

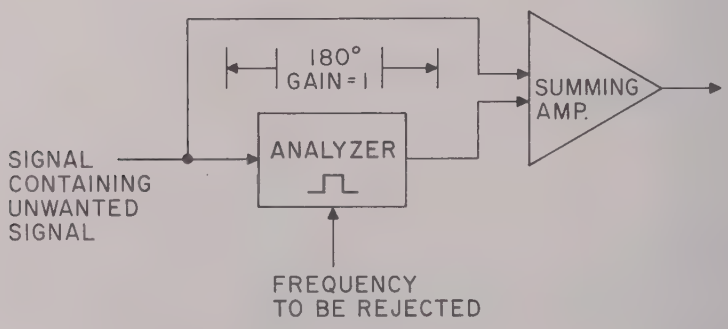
X. PHASE MEASUREMENTS

Slight modifications will enable phase measurements of a noisy signal to that of a standard signal. Two (2) analyzers may be employed to obtain phasing of two noisy signals.



XI. FREQUENCY TUNED BAND REJECT OR "NOTCH" FILTER

Utilizing the demodulated output of the analyzer a phase shift of 180° and unity gain through the analyzer may be established to allow rejection of the signal to which the unit is tuned.



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SOME EFFECTS OF ACCELERATION WAVEFORM DISTORTION IN SINUSOIDAL VIBRATION TESTING

By: Donald L. Wrisley
Wrisley Engineering, Inc.
(Winchester, Mass.)

THE PRESENCE OF DISTORTION in the acceleration waveform at some frequencies in the range encompassed by most vibration test specifications is well known. Most frequently, this is the result of small amounts of harmonics in the output of the power supply being amplified by "High Q" mechanical resonances in the moving system--very often the fundamental axis resonant mode of the shaker armature. (Although serious distortion is sometimes the result of shaker body resonances and of non-linear loads.)

For most modern shakers with force outputs above 1,000 pounds, the fundamental axial mode occurs at some frequency between 1,500 cps and 5,000 cps for no load, and of course at progressively lower frequencies as table loading is increased. It is readily evident that 3rd harmonic distortion of fundamentals between 500 cps and 2000 cps present in the power supply output can excite these mechanical resonances. And because these resonances are very lightly damped, the 1/2% to 3% distortion present in the best of amplifiers can be magnified to the extent that acceleration waveforms with 20%, 50% or greater harmonic distortion are not uncommon. Figure 1 shows some typical waveforms containing 3rd harmonic distortion of these orders of magnitude.

TABLE 1. True Peak Acceleration (G) for 10 G Peak Acceleration Indicated on Typical Averaging Meter

Amplitude of 3rd Harmonic as a % of Fundamental	True Peak Acceleration, G				
	0°*	30°*	60°*	90°*	180°*
0	10	10	10	10	10
10	8.7	9.2	9.8	10.4	11.4
20	8.2	9.0	10.5	11.1	12.2
50	9.2	10.5	12.1	13.9	18.0

*Angle in degrees by which 3rd harmonic leads fundamental.

Let's take a look at what this means in relation to monitoring and automatic control of acceleration level.

First of all, most vibration systems include a monitor or vibration meter. This is usually a vacuum tube voltmeter which provides readout on a conventional rectifier type meter--an averaging device. The scale reads in terms of peak acceleration, which, for a pure sine wave, bears a known relationship to the average value of the acceleration waveform. The simple, known relationship is destroyed, however, in the case of a waveform with even a modest amount of harmonic content. To complicate things further, the phase of the harmonic relative to the fundamental drastically affects the relative magnitudes of peak and average values of the waveform. Table I shows the true value of peak acceleration for the case where INDICATED peak acceleration is held constant using an averaging meter calibrated in terms of peak. Shown are the effects of phase as well as magnitude of 3rd harmonic distortion.

From Table I, it is apparent that indicated acceleration under these circumstances is quite unreliable, and the true peak acceleration can be lower or dangerously higher than our meter would have us believe. For example, in the worst case tabulated, the true peak acceleration is almost twice that indicated.

Next, let's look at this in terms of servo controlled, swept sine tests. If the servo system samples a feedback signal that is proportional to the average value of acceleration (and some do), then we have a situation like that above, and our test specimen may be subjected to peak accelerations far greater than called for. If our meter is the averaging type, we will not see this. If our meter is a true peak reading meter, it will indicate this and the impression may be that the servo system is not holding level properly. On the other hand, if the servo system operates on a feedback signal proportional to the peak value of acceleration (and again some do), we have a slightly different situation. We are now perhaps more nearly meeting the intent of the specification (most of which are written in terms of peak acceleration), and we are certainly treating our specimen more gently. But, if our meter is the averaging type, we must recognize that again it is not going to give a true indication of the peak value of acceleration. This is shown in Table II, which gives the value of peak acceleration that would be indicated by the averaging meter when the true peak acceleration is held constant. Again, the effect of phase relationship between fundamental and harmonic is given for three levels of 3rd harmonic distortion.

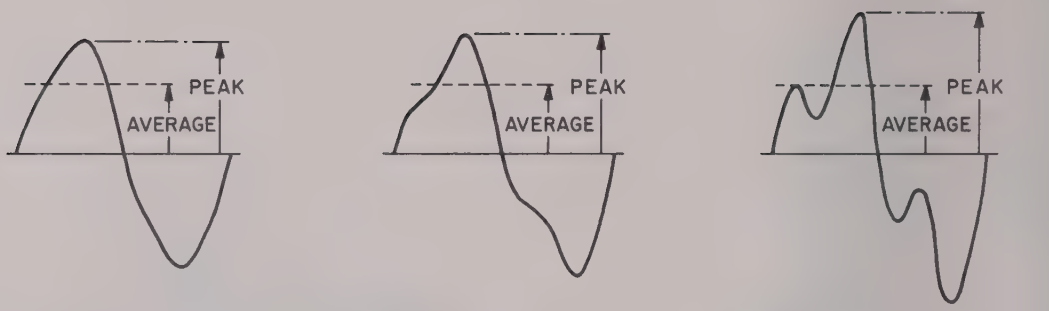
TABLE II. Peak Acceleration as Indicated by Averaging Meter for 10 G True Peak Acceleration

Amplitude of 3rd Harmonic as a % of Fundamental	Indicated Peak Acceleration, G				
	0°*	30°*	60°*	90°*	180°*
0	10	10	10	10	10
10	11.5	10.9	10.2	9.6	8.8
20	12.2	11.1	9.9	9.0	7.8
50	10.8	9.5	8.3	7.2	5.6

*Angle in degrees by which 3rd harmonic leads fundamental.

Further, when we remember that the phase of the mechanical response changes as we go through a resonance, we can expect our meter to perhaps read both low and high within a very narrow frequency band as the fundamental passes from below to above 1/3 the mechanical resonant frequency.

In view of the terminology of most specifications, it would seem desirable for the vibration equipment manufacturer to use feedback proportional to peak value of the acceleration waveform and to provide a true peak reading meter on which to monitor acceleration level. In addition, the use of a cathode ray oscilloscope to continuously observe acceleration waveforms obviously recommends itself. However, our purpose here has been more to present this fact of life and the nature of things to the TEST ENGINEER who has the problem now! We may not like it, but understanding does make it easier to live with, and may make acceptable a test which otherwise might be ruled unacceptable. END

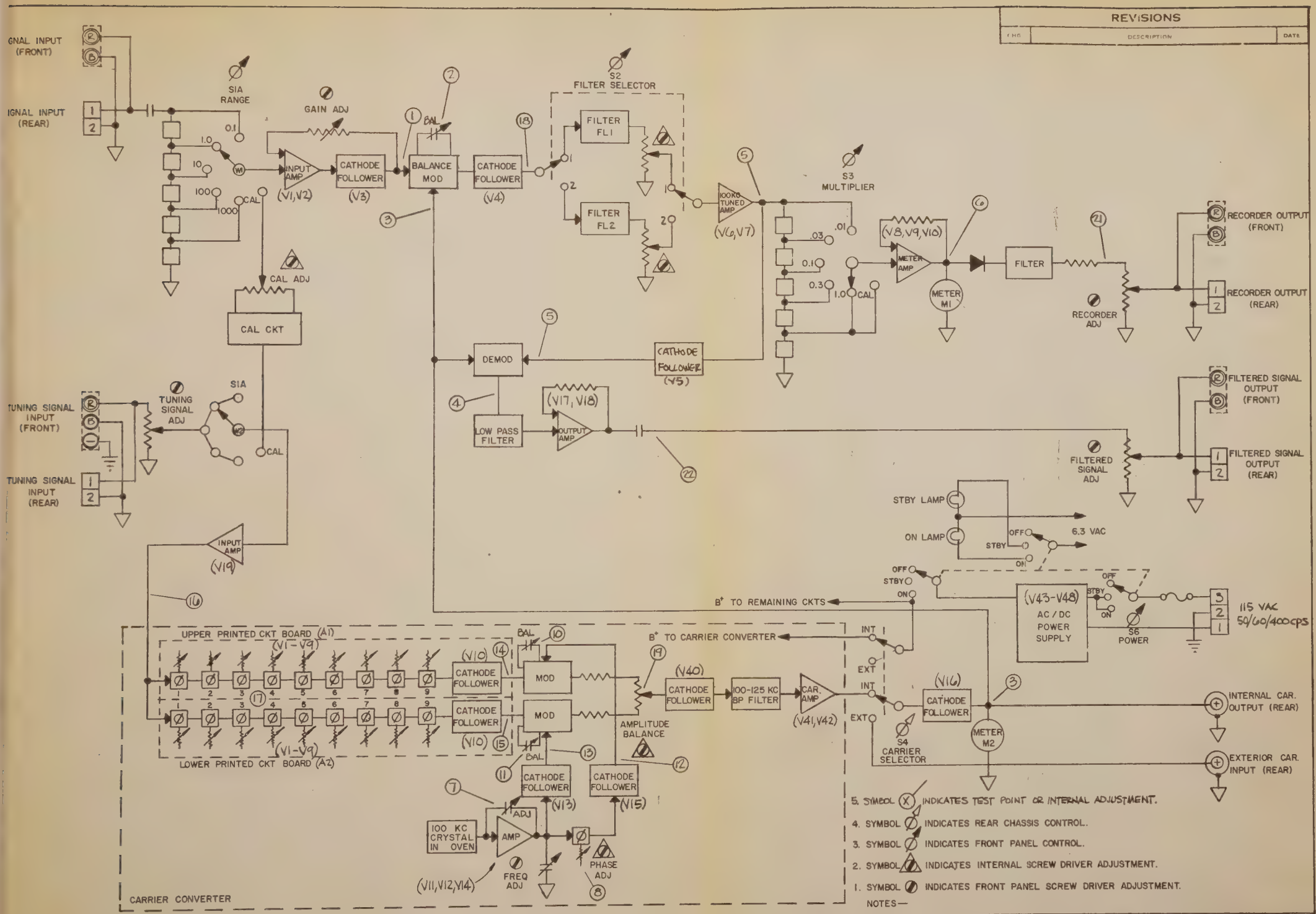


AMPLITUDE OF 3RD HARMONIC - 10% OF AMPLITUDE OF FUNDAMENTAL PHASE -- 90° LEADING

AMPLITUDE OF 3RD HARMONIC - 30% OF AMPLITUDE OF FUNDAMENTAL PHASE -- 90° LEADING

AMPLITUDE OF 3RD HARMONIC - 50% OF AMPLITUDE OF FUNDAMENTAL PHASE -- 90° LEADING

Figure 1. Typical Acceleration Waveforms Containing 3rd Harmonic Distortion. Note that for This Particular Phase Relationship Average Value is Unaffected by Amount of Harmonic While Peak Value is Drastically Changed.



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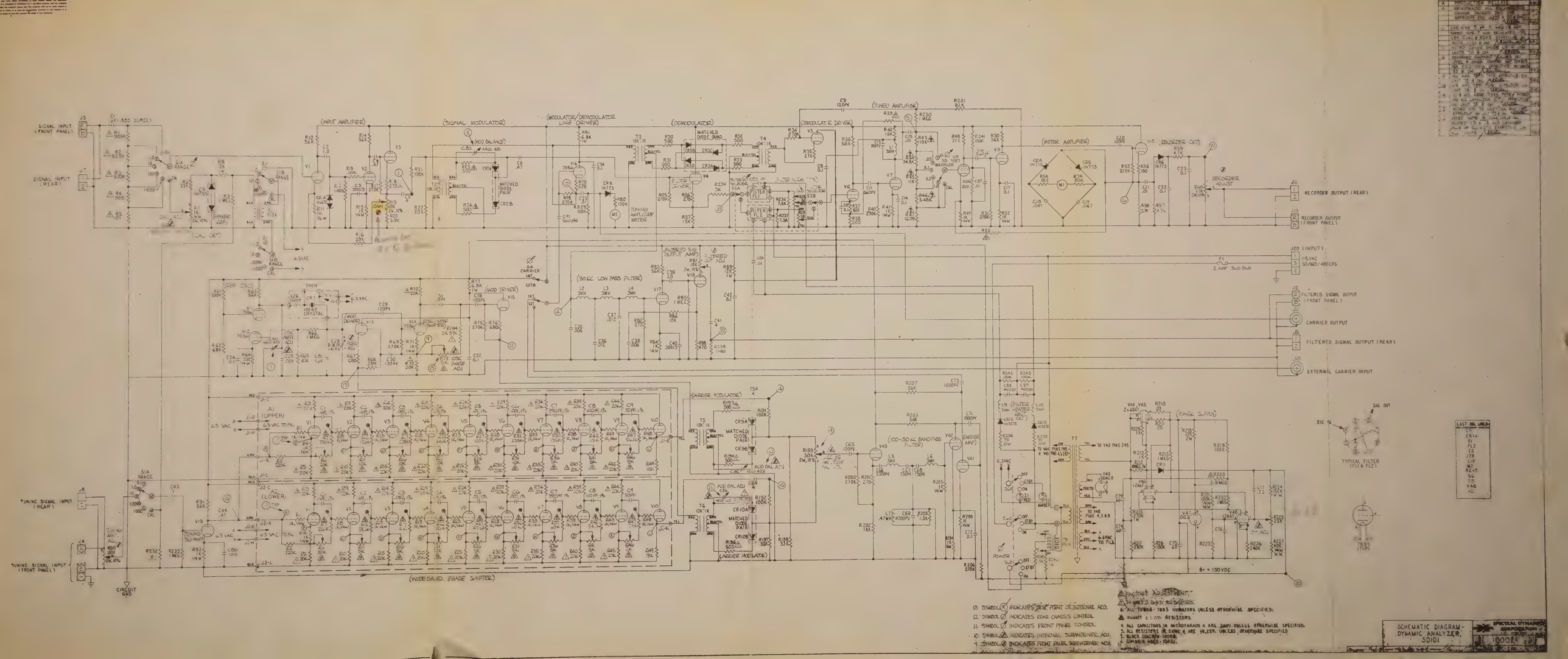
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SIGNAL INPUT (REAR)
(INPUT AMPLIFIER)
(SIGNAL MODULATOR)
(MODULATOR/DEMODULATOR LINE DRIVER)
(DEMODULATOR)
(DEMODULATOR DRIVER)
(TUNED AMPLIFIER)
(METER AMPLIFIER)
(RECORDER CKT)
RECORDER ADJUST
RECORDER OUTPUT (REAR)
RECORDER OUTPUT (FRONT PANEL)
(OSC)
(MOD DRIVER)
(MOD DRIVER)
(300 KC LOW PASS FILTER)
FILTERED SIG OUTPUT AMP)
J20 (INPUT)
115 VAC 50/60/400 CPS
FILTERED SIGNAL OUTPUT (FRONT PANEL)
CARRIER OUTPUT
FILTERED SIGNAL OUTPUT (REAR)
EXTERNAL CARRIER INPUT
(CARRIER MODULATOR)
(100-150 KC BAND PASS FILTER)
(CARRIER AMP)
(POWER SUPPLY)
TUNING SIGNAL INPUT (REAR)
TUNING SIGNAL INPUT (FRONT PANEL)
CIRCUIT GND
(WIDEBAND PHASE SHIFTER)
TYPICAL FILTER (FL1 & FL2)
B+ = 150 VDC
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